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FOOD TECHNOLOGY

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FOOD TECHNOLOGY

VOLUME 2 APRIL, 1948 NUMBER 2

Editorial

Good Human Relations Pay Dividends[1]—

Charles P. McCormick[2]

More than three hundred years ago, the Pilgrims brought to this country the fundamentals of democratic government, based on belief in the "Dignity of Man." In return, those pioneers received a noble, undeveloped heritage that has provided our nation with a standard of living unknown to any other people on this earth.

The individual freedom planted in this land by those early settlers and nurtured and developed throughout the years, even at the cost of life and treasure, has made us the strongest nation in the world. Now, you may rightly say to yourselves, that there is nothing new in this thought, and I will agree. But my point in repeating it today is this; that individual freedom and free competitive enterprise deserve full credit for giving all the people of the United States the highest standard of living in the world.

It has been the accomplishments of the American form of capitalism that have provided us with many things we consider essential today, but which were unavailable before the era of large scale production. Neither government nor labor, nor any organized groups have been responsible for our progress. It has been the ability of business management to put theory into practice, that has placed the fruits of science and invention within monetary reach of the average man.

And now, our system of free enterprise is in danger, because many of us have lost sight of our responsibility to protect the dignity of the individual—we have forgotten that there is such a thing as the "human equation."

May I digress and give you an interpretation of the phrase "human equation" as it appeared in a recent *Saturday Evening Post* article. The writer, a youthful Army Air Forces veteran, wrote:

> "The human equation is simply human nature that has defied both law and reason since man was created. It is people being born with varying degrees of brain power and different personalities. It causes us to sigh at the death of a million Chinese and cry at the death of a pet dog. It causes us to believe that skin color and intelligence have a definite relationship. It makes a miser out of some people and philanthropists out of others. It goes among the poor and finds an Abraham Lincoln, a Booker T. Washington and an Enrico Caruso. It laughs at both kings and paupers. In short, *it insures against any two persons thinking alike on all subjects.*"

The unfettered application of the "human equation" in our daily routine has been the guarantee of our rights and freedoms, essentials to the maintenance of healthy free enterprise. Therefore, it is most important for us to keep in mind our obligation to give free reign to the "human equation."

About the same time the Pilgrims landed in this state, a very wise Spaniard made a statement which is still good today. He said: "Three things make the superman, and they are the greatest gifts of divine generosity; a fertile mind, a deep under-

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[1] Presented before the Seventh Annual Food Conference, Boston, Mass., June 2, 1947.

[2] President, McCormick & Company, Inc., Baltimore 2, Maryland.

standing, and a cultivated taste. A great advantage, to have a good imagination; but a greater to be able to think straight. Straight thinking is the fruit of reason."

And there is nothing wrong with our economic situation that cannot be cured by the application of straight thinking along Human Relations lines. We've got to reinstitute into our business life, the principles and practice of regard for the welfare of our fellow man. But the enthusiasm and direction has got to come from the top, from the leaders of the business, before others will follow. And there never was a better time than the present, for management to take a fresh look at its industrial relations' practices and to check them against new and improved techniques. We all need to look forward to a new horizon of better employer—employee cooperation which will help assure greater production, additional jobs and more security of employment. Each of us should start to act so that the law of his life may well become the law of all mankind.

Employers must operate their businesses unselfishly, looking to the overall good of the entire operation. It is only by virtue of unselfish thinking that we can establish our modern business structure on a firm foundation with a greater return and protection for all, as opposed to a selfish policy which ultimately leads to misunderstanding, strikes and anger.

To my mind, a good first step is to place men ahead of machines in our business thinking. In our company, a food manufacturing business, we evaluate all potential executive talent more carefully than we evaluate a fifty thousand dollar machine. We feel that a leader for the future must be prepared by experience in the present, while a machine purchased today may be discarded after a brief interval because of deterioration or improved inventions. Experience builds a man, while deterioration and use takes a toll of all machinery, and a man has the capacity to build a better machine or let it remain idle. That is why we put a price on each prospective executive so that we won't overlook our fifty thousand dollar human machines. It then becomes our responsibility to see that they are trained and used to the maximum of their individual capacities. There are millions of dollars of untapped skill in American industry, all because our Science of Human Relations has not kept pace with our material Scientific Achievement. It is imperative that we realize Human Relations is a study that will bring equal and more lasting developments for the future welfare of our nation.

Think for a moment what sound Human Relations' policies can mean to this country, its industry, its labor and its government. There would be a minimum of strikes; there would be a maximum of production; there would be fewer business failures, and our taxes could be lower—all because of man's thinking. This field is an unexploited gold mine beneath our feet, and this gold mine ultimately may be the most secure starting point for a better understanding of nations and for a lasting peace.

The current struggle between labor and management will seriously affect the future of our country, as long as the two factions face each other across a gulf of fear and hatred, and fail to recognize the common ground in between. So long as this situation occurs, just so long will the principles that we believe in under our Constitution be but symbols.

The burden of responsibility for our present unsatisfactory economic situation must be shared equally by labor, management and government; because of poor cooperative planning, and failure to think unselfishly of the other groups. Because of this woeful lack of preventative thinking, millions of Americans are now being affected by this bitter economic battle. To the consumer public, it matters not what

the motives are for the nation is suffering from lack of leadership, unity of purpose and from pressure groups that dominate Congressional legislation. I believe that the logical leader of labor is the employer. He had the job years ago before he lost contact with his employees. He can regain his position provided he is able to restore two-way communication between himself and his employees by returning to the "Dignity of Man" principle. A very valuable instrument for re-establishing this two-way communication should be a carefully executed Human Relations program.

Therefore, the most urgent duty of every business executive today is to make himself an expert in human relationships. Above and beyond the cold factual "know how" of machines, finances, selling and merchandising, which he has always considered his province, tomorrow's "top man" must be familiar with the minds of the people associated with him in order to anticipate their needs and desires and to prevent strife and discord. He must be able to deal with all types of people, not just his own "clique."

At McCormick & Company we do not speak from special knowledge, but we have delved into Human Relations possibly more seriously than any other firm in the country. In our effort to find some of the solutions to industrial personnel problems, we have reached certain definite conclusions, and we feel that backtracking on yesterday and endeavoring to correct the errors of that day, is unimportant. But we do feel that to do something constructive today, for the future, is most important.

We can offer only a few factual suggestions based entirely on our past fifteen years of thinking in terms of harmony in business, of cooperation with labor, and increased production through participation in management. Perhaps these are only general human principles, known originally to everyone, but soon forgotten by overly-ambitious men who are elected to leadership positions.

Our first thought is that the chief executive of each group should begin to think of himself as a "trustee" and not a "boss." Would it not be dangerous for a sea captain to thrill only with the knowledge that it is within his power to dash a thousand lives on the rocks, rather than to take pride in his ability to bring his vessel safely to port? If the leaders of business, labor and government can develop and demonstrate this sense of public and private trusteeship, then perhaps the "first bridge" will have been thrown across the chasm separating labor and management groups.

A "second bridge," more appealing to the average employee, is erected when the front office uses its trusteeship so that every person is rewarded equally for the talent and effort expended industrially, whether by janitor, mechanic, or director.

The "third bridge" should be some plan whereby office, factory, in fact, all employees may feel free to state their views and opinions to top management without fear of the consequences should the unadorned truth prove hard to take, as it most usually is.

America can only remain free if government and management will allow labor to have freedom of speech and opportunity. On the other hand, organized labor must find a way to be a helpful ally by lending support to good management through high production and increased efficiency. Wages can be paid only after they are earned and the higher the wage, the better for all concerned, provided the rate and efficiency of production are equal to the wage.

Therefore, it seems that an advantageous adjustment in our economic system can be made by the substitution of *faith* for *fear*. Fears grow out of lack of security and ignorance, and all dictatorships and bureaucracies thrive on such a diet. A free

man must be convinced that his views will be given a responsive hearing, that he will be given freedom of opportunity with no limit on his earnings or his future progress. Fear will never be eliminated as long as issues are concealed behind closed doors; as long as we have censored news; and as long as we have *fear* in any form, induced by strikes or lock-outs or forced legislation.

Free enterprise was practiced in early New England days—nothing new, yet deeply American in tradition. The capitalist of the day was the man who had accumulated enough money to start an enterprise—whal[illegible], for example. When he signed on his crew to operate the vessel, every man [illegible]eard knew just exactly what was expected of him—that the voyage would bring d[illegible]ers as well as rewards. The rewards were customarily a well-understood share in the haul apportioned according to a scale agreed upon as fair before the voyage, by all from the Captain down to the cabin boy. Every member in the venture had the complete picture and the crew worked harmoniously together as long as the owner kept to the terms of the agreement. Then, if a capitalist wasn't fair, he found it impossible to sign up a crew to operate his vessel.

But we've come a long way from those rugged yet profitable days. As our business grew in size, somewhere along the way the men at the top, responsible for the thinking and direction, let more immediate problems crowd the human element out of the picture. It is true that the cabin boy and the deckhand were given more money, but the earlier pride of participation and possession and sharing was lost in the shuffle. In the olden days, all hands knew that as they increased their efforts they were, at the same time, increasing their share in the profits. Later, many got the impression that they were not "paid to think," that they would get a flat rate for the job they took when they "signed aboard," and that was that. Today labor seems to be more interested in obtaining its viewpoints, rather than helping a man to increase his earnings to the fullest extent of his talents. Some ambitious men want to work longer and harder, but they are hampered by rules and regulations. This, too, is contrary to man's progress. Under such conditions enthusiasm, probably the greatest of all production tools, has become dull.

At McCormick's the first attempt to solve some of these problems was made in 1932 with the installation of our Multiple Management plan. We have attempted to bridge our chasms with the aid of subordinate management boards, which bring together all the ideas of the thinking people in the organization for the betterment of the business as a whole, and the increased welfare of the people in it.

Multiple Management extends the opportunity of participation in the affairs of the company directly and actively to every thinking employee at the supervisory level and above. It provides for Boards of Directors made up of men right out of the office, plant, and sales organization, men who are on their way up, to supplement the Senior Board of top-management men. We began with a Junior Board of Directors back in 1932.

We selected seventeen men—assistant department heads, accountants, junior executives, etc.—whom we considered to be the best prospects for future leadership, and told them that they were to be given direct participation in management in their own group, operating independently of the Senior Board and the line organization.

They were told to elect their own chairman and secretary, set up their own schedule of meetings, draw up their own By-laws. They were given the right to discuss anything in the business which interested them. They were assured that top management would not be present to look over their shoulders in the meetings, and

that their discussions would be free discussions without "top-side" interference. They were given suggested projects and topics, as a starter, to give them an idea of the sort of subject matter on which the company could use their thinking.

There were two practical and realistic brakes put on them which have not interfered with their free action, but have given the business every protection any business wants. They were told, first, that every recommendation from their Board must be unanimous. If the original idea cannot be sold to the entire group around the table, revise it and amend it so that the finished idea is thoroughly thought out and sound. Secondly, their recommendations do not go into final operation in the company until the President, or the Senior Board of Directors has approved them and made sure that no conflict or duplication exists.

In the first five years, 2,109 unanimous recommendations came out of the Junior Board and from the Factory Board, established shortly after the Junior Board, with plant and warehouse men as its membership. Of this number, only six were turned down completely. This meant that 2,103 fresh new ideas found their way into company operations and policies. Since ideas are the life-blood of business, the business prospered from this harnessing of the potential creative thought of alert, aggressive, middle-management men.

The Factory Board also was appointed at the beginning and operates the same manner as the Junior Board. Holding regular meetings, the members discuss matters of production, shipping, and warehousing—things with which they are concerned in their daily jobs; and make many recommendations for improvement of plant procedures and techniques.

The Sales Board of Directors was a logical development at McCormick's because the business is divided into three parts—office, factory and sales. The Sales Board is made up of men right out of the sales organization. Since they are scattered from Maine to California, this Board presented a special problem which was solved by arranging for meetings lasting a week, twice a year. Between meetings the members carry on their work, through committees, by correspondence.

There is a Consumer Board made up of women to make recommendations on products from the standpoint of recipes, packaging, advertising, etc.

The Senior Board of Directors is elected annually by the stockholders and corresponds almost identically to the Board of Directors of the average corporation. No member of the Senior Board of Directors may serve on the Junior, Factory or Sales Boards. They attend subordinate board meetings by invitation only.

Thus, instead of the usual half dozen or dozen people active in management on a board of directors, McCormick and Company has over fifty people serving as directors of the company. Their ideas are brought forth in free discussion; and their management responsibilities supplement, but do not replace, their regular duties in their departments as parts of the line organization of the company.

Although the original Junior, Factory and Sales Boards were set up by the President by appointment, the By-laws of each provided that thereafter members should be selected by merit ratings done by the board members themselves. Thus, every six months each Junior Board member, for example, rates every other member except himself on a chart which provides points for each of several executive qualifications, such as Human Relations, vision, initiative, judgment, etc. The six men who rate highest become the Membership Committee and choose the balance of the board for the next term, considering every potential executive in the company as eligible. The three men who rate lowest are dropped from the board, but are told

the reasons why by the Membership Committee and are assured that if their points of weakness are improved, there is a good chance for their being selected to return to the board six months later.

Management has been brought close to McCormick workers by this series of boards. A Factory Board member communicates to workers some of the problems and difficulties facing top management, and the workers of the business, because he learns about them in board meetings; and in the same fashion workers communicate to board members their feelings and wishes. They are close enough to them to speak freely. Therefore, their suggestions and their requests are passed along rapidly in the very next Junior or Factory or Sales Board meeting and come up to management quickly for prompt attention and action.

In these days of labor strife and turmoil it is pleasant to be able to report that there have not only been no work stoppages at McCormick and Company in these fifteen years, but actually there have been no whispers of labor discord, no petitions from employees, no demands for changes in policy—nothing but harmony. One reason is that management is working in the interests of the people and is close enough to them so that employee wishes and requests are put into effect as company policies, by board action, before they ever reach the stage of becoming a demand. In other words, management takes the initiative in Human Relations.

This has brought about an invaluable spirit and morale. Our employee turn-over is 3 to 5% in normal peacetime years. Unexcused absenteeism in wartime was always less than 1%. Employee wages are the highest in our industry in our area and are supplemented by profit-sharing bonuses, plus a program of benefits, including a company-paid pension plan, group insurance, sick benefits, complete medical service and so on. The great majority of our most competent and efficient employees, in the group having six months or more service with the company, are assured 48 weeks of work stabilized employment in an industry which formerly hired and fired three times annually. There is no piece work in our plant, and all employees have paid vacations and holidays.

We have found that people working in business appreciate these things and reciprocate their appreciation. In addition to avoiding the plague of work stoppages and slow-downs, we have found that our people have maintained efficient productivity and even increase it when called upon for special effort over a given period in the interests of building up a lagging profit. They have a direct incentive in the form of bonuses which are paid in proportion to profit earned.

The Middle-management group has been recognized by eligibility to serve on boards as being definitely a part of the management organization. There is no issue of whether a foreman, for example, is management or not at McCormick's. Men who otherwise would have little opportunity to display over-all management ability in their regular departmental jobs get a chance to show what they can do in board discussions and meetings on management contributions for the entire business.

We have found that this discovery of talent and training of future leadership is a valuable by-product to supplement the employee morale and the idea producing values of the boards to the company.

But I think the real point is that workers have increased earnings, management has received a direct return in the form of increased profits, and capital (meaning stockholders) has received a direct return in the form of increased dividends. All because of Multiple Management. Thus, everybody has benefited. Our fifteen years of experience, and reports from several hundred other companies which have

adapted Multiple Management to their organizations, prove by results that it pays for management to take the initiative in better Human Relations.

We humbly contribute this experience in the vast field of Human Relations, as our small share toward a better understanding between the men and women who make up the fabric of business in America. Our country is better off in a material way than any other in all the world. We have only to clear the air of doubt and suspicion and get on with the job ahead. We at McCormick believe the means of solving the problems of the day are right within our grasp, if only we will open our eyes and deal with them. Multiple Management may, after all, become a small candle in the darkness of laboring strife that may encourage others to revert to early American thinking.

Through education and team play, peace in industry *can* be won. During the recent war it was the continuing and unrelenting team play of the civilian, the government and the military that won the war. All could not be at the front, but all could play a part in winning the victory. Government *can* learn to be a servant; management a trustee; and labor a cooperative productive ally.

There is nothing new in these thoughts which I have reiterated here today. The pattern for our standard of living was established by those far-sighted Pilgrims over three centuries ago. There is no short cut to improvement. We've got the highest standard of living in the world because individual freedom and free competitive enterprise have made it possible.

When a man ceases to work, he dies; when men in opposing circles fail to cooperate, the nation starts to die. It seems to me that the cure for this deficit-ridden world is greater production of usable things in a smoothly functioning economy based on our proven system of free competitive enterprise. God give us a victory of peace as well as of war—with as few casualties as possible.

Editorial

Efficiency in Changing the Institute Administration

The original Constitution of the Institute of Food Technologists, after a long period of preparation, was adopted June 16th, 1941. Three important provisions of that Constitution have undergone major modifications in the two revisions that have taken place.

In this issue of FOOD TECHNOLOGY, the Constitution is printed for the first time since the second revision was approved in February. It seems appropriate to discuss here the most important features of the revision.

The three provisions referred to above were (1) four classes of members, (2) very democratic nomination procedure, (3) "lame duck" period.

Here is the history of those three provisions.

Many suggestions were offered by Members during the years since 1941 relative to changing the requirements for membership. Most of the suggestions, however, when analyzed, seemed to propose little more than a continuation of the system already in effect, with a change of names for the different classifications; therefore they acquired little support by either the Council or the Committee on Constitution. A point that did take hold, however, is that, in a professional society, there is no place for Corporate Members. Corporate Membership was eliminated, therefore, in the last revision. No other change in the membership system was made.

As is true of all purely democratic processes, the procedure set down originally in the Constitution for making nominations was cumbersome. Most chairmen of the Committee on Nominations have become discouraged in trying to conduct the work of the Committee in the prescribed manner.

As the number of persons with experience in serving on the Committee on Nominations increased, sentiment in favor of a simplification of procedure was strengthened. Through the growth of this sentiment, and through argument in favor of simplification, the strength of the support of the ultra-democratic method of procedure was broken and a modified procedure was incorporated into the revision which was just adopted. The major change effected brought an endowment to the Committee on Nominations of power to place the names of an established number of Members before the voters as recommended candidates for the various posts. Voters still have the right, however, to place on the ballot the names of any eligible persons, whom they wish to recommend as candidates for the various offices. Thus, the democratic nature of the system is fully retained; at the same time, the likelihood is established that the total number of names suggested for nomination will be much smaller than under the former system. Formerly from 100 to 200 Members received votes for nomination to the eight posts which are filled in each election.

Article V of the original Constitution provided that "the duties of office shall start with the beginning of the first fiscal year of the Institute following the election." Since the fiscal year was coincident with the calendar year, more than six months elapsed between the election and the time the officers and Councilors at Large assumed their duties.

This "lame duck" period usually was not productive of either efficient operation of Institute machinery or good preparation for such operation during the next fiscal year. To remedy this situation, the 1944 revision contained an amendment to Article V, providing that "the duties of office shall start at the close of the annual meeting at which the election results are announced."

Council then changed the fiscal year to June 1-May 31.

Improvement resulted from these changes, but there was still an unsatisfactory feature. Two or three months of the President's term of office were consumed in getting the committees organized, so there still was a period following the annual meeting during which constructive action was difficult.

It was decided that the "lame duck" period is not inherently bad. It becomes bad only by virtue of its being wrongly placed. On this philosophy, an amendment was drawn up to establish a "transition" period immediately before the annual meeting. This period is not in fact a "lame duck" period because the President-Elect is an officer of the Institute between the time of the announcement of his election and the next annual meeting. Duties are specified for the President-Elect during this period, which is at least four months in length. These duties "consist of building an organization for carrying on the functions of administration during his term as President and of becoming acquainted with the nature and activities of the Institute." It is hoped and expected that this building and planning activity by the President-Elect for his future work will be carried on with the zeal which characterizes Institute affairs in general during the period immediately preceding the annual meeting, so that the work of the Institute will proceed without interruption upon the accession of the new administration.

One result of this revision of the Constitution, which all Members should bear in mind, is that there will be two elections in 1948. By September 1st, nominating ballots will be in the mail carrying at least 35 names of Members recommended by the Committee on Nominations for consideration by the voters, and, on November 15th, the election ballots of the first election in which a President-Elect will be chosen will be in transit to all Members. Be prepared for the election this fall.

While on the subject of Institute procedures, including the matter of membership, we shall repeat the instructions which were given in the corresponding issue of FOOD TECHNOLOGY one year ago on how to become a member.

How to join the Institute of Food Technologists

The procedure for joining the I. F. T. is as follows:

1. Fill out an application blank.

   If the applicant resides within the area covered by a regional section, the application form should be obtained by writing to the Secretary of the section. These are listed, with addresses under "News of the Institute" in the July, 1947 number. If the applicant resides far from the headquarters of a regional section, the application form should be obtained by writing to the Secretary of the Institute, Amherst, Mass.

   The application blank calls for information regarding the training of the applicant in the field of food technology. Since the question of qualifications is important, it is necesary to obtain the endorsement of three Members. If the applicant is not acquainted with three persons whom he knows to be Members of the Institute, he should ask the person to whom he writes for the application blank to give him the names of several Members in his locality, to whom he might become known.

2. Send the completed application to the office from which the blank was received.

   If the application is submitted to the Secretary of a regional section, it is first referred to the section Committee on Membership Qualifications and then sent with the recommendations of that committee to the Secretary of the Institute. The Secretary submits the application promptly to the Institute Committee on Membership Qualifications, which makes a recommendation to the Council as to the type of membership to which the applicant is entitled on the basis of his qualifications. The Secretary secures action by the Council and reports the results to the applicant and to the Secretary of the regional section.

If the application is submitted by the applicant directly to the Secretary of the Institute, the procedure is as described above, following the receipt of the application by the Secretary. In such case, however, if the applicant resides within the area, covered by a regional section, the first step of the Secretary upon receipt of the application, usually is to request a recommendation from the Committee on Membership Qualifications of the section.

C. O. BALL

ELECTRONIC PRESERVATION OF BOSTON BROWN BREAD[a]

JAMES W. BARTHOLOMEW, R. G. HARRIS,[b] AND FRANK SUSSEX
Department of Bacteriology, University of Southern California, Los Angeles, California

High frequency heating can be used to prevent molding of wrapped unsliced bread. Heating in a dielectric field was possible; however, heating in an induction coil was more rapid, and the heating effect was largely confined to surface areas where it was most needed.

W. H. Cathcart *(1, 2)* has reported a method of producing mold free bread by application of the heating effect of a high frequency dielectric field. Heating of an object in a high frequency field can be accomplished by two methods. If the object is an electrical conductor it can be surrounded by an induction coil. In this case the heating effect appears first on the outer surface of the object and the center may remain cool. If the object is a nonconductor of electricity, heating is best accomplished by placing it in a dielectric field. In this case the heating effect is distributed throughout the mass and if the material is homogeneous, the center of the object is heated at the same rate as the outer surfaces. Since the heat is generated in the object itself it is never necessary to have any direct contact between the object being heated and the high frequency apparatus. Thus, it is easy to treat wrapped items without damaging the packaging material. The basic theory of dielectric and induction heating has been summarized by Kinn *(3)*. The present paper is a report on attempts to prevent molding of Boston brown bread by various high frequency heating methods.

METHODS AND EXPERIMENTAL RESULTS

The machine used in these experiments was designed by the Electronic Chemical Engineering Co. of Los Angeles, California. It operated at a frequency of 26 megacycles with a power input of approximately 3.3 kilowatts and a power output of approximately 1.7 kilowatts. The electrodes consisted of two copper plates six inches square and were spaced about six inches apart. The bread was held five-eighths inch from contact with either of the copper plates by Pyrex glass dishes. This prevented most of the burning from "arcing" which occurred if the Pyrex glass was absent. Figure 1 illustrates the plate arrangement.

The most frequent cause of bread spoilage is mold growth, consequently an experiment was first conducted to determine what treatment was needed to kill mold spores in a dielectric field. *Penicillium* and *Aspergillus* spores were suspended in distilled water and diluted so that each contained approximately 75,000 spores per milliliter. Five milliliter samples of these suspensions in glass test tubes were exposed to various treatments in a dielectric field. The treatments and results are reported in Table 1. Exposure to the dielectric field produced a heating effect which raised the temperature of the suspension from room temperature to 150° F. (60.5° C.) in 60 seconds time. After each treatment the suspensions were immediately removed from the field and placed in cold water. The number of viable spores was determined before and after treatment by the plate count method.

From Table 1 it can be seen that a 60 second exposure of the suspension to a dielectric field produced a temperature of 150° F. (60.5° C.) which was sufficient to kill a "load" of approximately 75,000 mold spores per milliliter of water

[a] This paper was presented in part at the May 22, 1947 meeting of the Southern California section of the Society of American Bacteriologists.

[b] Now with the Texas Oil Co., Long Beach, California.

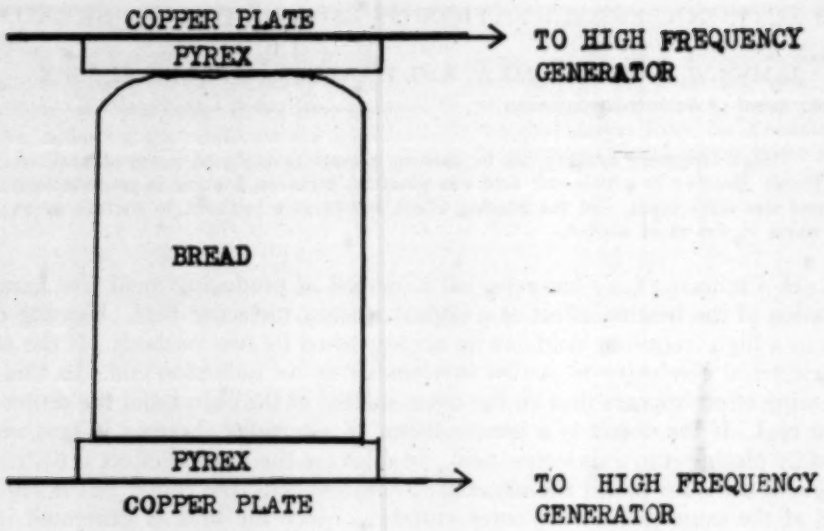

FIG. 1. Boston brown bread in a high frequency dielectric field.

suspension. Apparently, *Aspergillus* spores were more resistant than *Penicillium* spores.

When a loaf of bread is heated to 150° F. heat loss is rather slow after removal from the machine. Hence, heating a loaf of bread to 150° F. (60.5° C.) would be a more severe heat treatment than that represented by the above table. It was felt that heating bread to this temperature would represent a good margin of safety in the prevention of mold.

One hundred one-pound loaves of Boston brown bread were inoculated on the top surface with approximately 50,000 spores of *Aspergillus* and 50,000 spores of *Penicillium* and wrapped in cellophane wrappers. Each loaf was then placed in the dielectric field for a sufficient time to develop a temperature of 150° F. This took about three minutes on this machine. The loaves were then stored at room temperature. No special cooling technique was used. Ten loaves of bread were inoculated, wrapped and retained as the untreated controls.

The results obtained were excellent. All of the control loaves were moldy by the second day after treatment. None of the treated loaves showed any signs of molding by the end of one week after treatment, and only three were moldy by the

TABLE 1

Percent Survival of Penicillium and Aspergillus Spores Suspended in Distilled Water and Exposed to a Dielectric Field for Varying Lengths of Time.

Spores of	Suspension temperature after exposure to the dielectric field	Time of exposure to dielectric field	Count before exposure (spores per ml.)	Count after exposure (spores per ml.)	Percent killed
Aspergillus	120° F.	30 seconds	76,000	75,000	Not significant
Penicillium	120° F.	30 seconds	85,000	77,000	Not significant
Aspergillus	130° F.	40 seconds	75,500	75,000	Not significant
Penicillium	130° F.	40 seconds	79,500	18,500	77
Aspergillus	140° F.	50 seconds	78,000	60,000	23
Penicillium	140° F.	50 seconds	88,000	600	93
Aspergillus	150° F.	60 seconds	74,500	0	100
Penicillium	150° F.	60 seconds	76,000	0	100

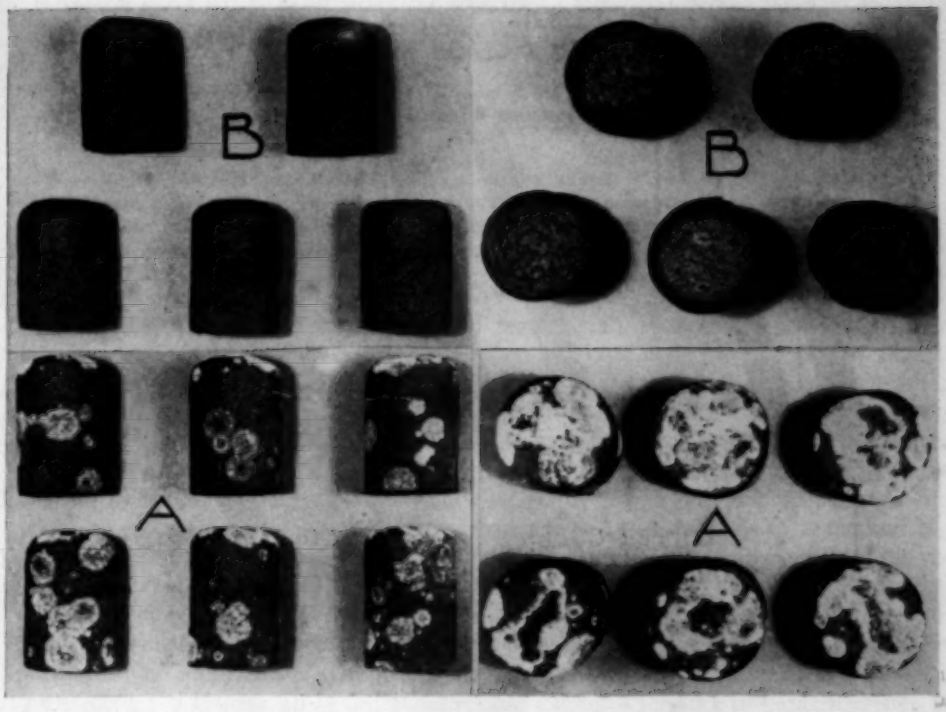

FIG. 2. Boston brown bread inoculated with *Aspergillus* and *Penicillium* spores and incubated at room temperature for one week. A—unheated controls. B—loaves treated in a high frequency field.

end of the second week. Photographs of treated and untreated loaves after a week's storage are shown in Fig. 2. The wrappers have been removed for the purpose of taking the photograph.

A copper coil was constructed about two inches longer than the usual loaf of Boston brown bread (Fig. 3). The diameter was sufficient to allow the insertion of a Pyrex glass sleeve to keep the bread from contact with the coil. One hundred ten one-pound loaves of Boston brown bread were inoculated with mold spores as previously described. One hundred were treated in the coil to bring the surface temperature of the bread to a minimum of 160° F. (70° C.). Ten were left untreated to serve as controls. The treated loaves showed no evidence of mold 14 days after the experiment. The control loaves were moldy by the second day. The induction coil was superior to the dielectric field as a method of heating Boston brown bread to prevent molding.

DISCUSSION

Heating in a dielectric field is very different from heating in an induction coil. In a dielectric field, the heat is distributed evenly throughout the heated object, the center being as warm as the outer portions. In induction heating the heating effect is mostly confined to the surface. Since most mold spoilage of unsliced bread is the result of mold growth on the bread surface, induction heating is ideal for killing these molds. Another possible advantage of induction heating would be the lack of a heating effect on the interior of the bread, since there is thus no tendency to promote rope formation because of prolonged high internal temperatures of the bread.

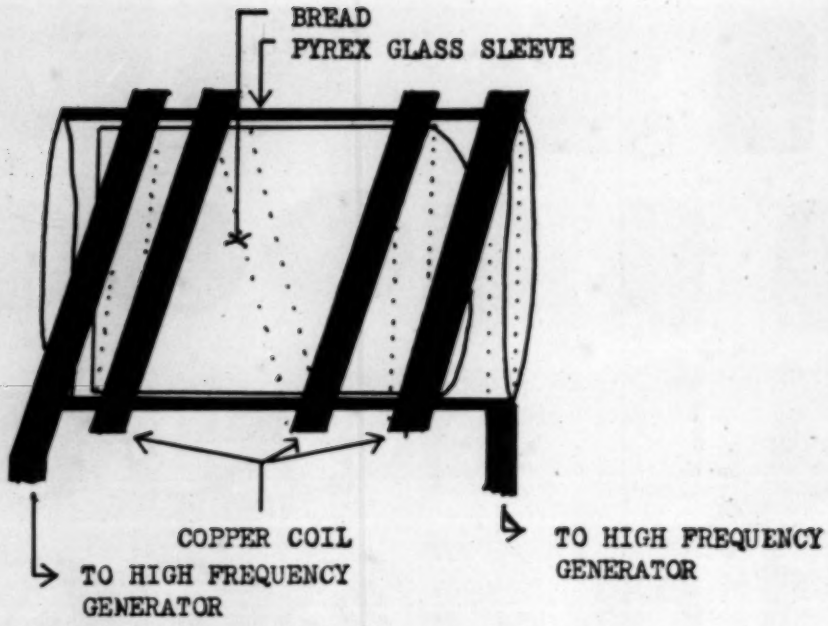

FIG. 3. Boston brown bread in a high frequency induction coil.

Bread heated in a high frequency field retained all of its natural appearance and "feel." Bread treated in an electric oven to kill molds emerged with a "case hardened" feel and proved unpopular with the consumer.

No attempt was made in these experiments to detect any lethal effect of the high frequency waves in the absence of heat.

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RADAR ENERGY FOR RAPID FOOD COOKING AND BLANCHING, AND ITS EFFECT ON VITAMIN CONTENT

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The application of radar energy to the baking of cakes, the cooking of meats and fish, and the blanching of vegetables is presented. The retentions of certain vitamins in the radar-treated foods and in foods cooked by conventional methods are compared.

INTRODUCTION

The use of electricity as a means of cooking and processing foods has been widely practiced for many years. The conventional methods have employed electric ovens or grids, which require fairly long periods of heating and depend on gradual penetration of the higher oven or grid temperature into the interior from the surface of the material to be cooked. More recently attention has been directed toward the use of dielectric heating, which differs from the conventional convection heating by the introduction of electrical energy through a field set up between two plates or electrodes in contact with the material to be heated. Such a method has been proposed for the pasteurization of milk *(10)*, wine *(13)*, and beer *(3)*, for the thawing of frozen foods *(4)*, for the sterilization of bread *(5)*, and for the blanching of vegetables *(9)*. Reports have also been made on the processing of food materials by electrical energy in the form of X-rays or Roentgen rays, which present a possible means of food sterilization without appreciable heating of the material heated *(12)*. Both X-rays and cathode rays have also been investigated as possible agencies in this field *(6)*. The ultra-short application of penetrating electrons as a tool for sterilization and preservation of food has also been studied *(2)*.

The present report is concerned exclusively with another and very recent means of heating food electrically, which originated during World War II from developments in the field of physics and electrical engineering, developments that made the radar an efficient military instrument. The magnetron tube, which is the basis of radar, generates radar microwaves that have been found to penetrate into foodstuffs and set up localized excitation of the molecules of food with the immediate effect of internal heating of the mass of food at a very high rate. Since the termination of hostilities, certain microwave bands have been released for purposes other than military. This present investigation relates to experiments using an oven (Fig. 1) heated only by the emanations of a magnetron tube generating microwaves at a frequency of approximately 3,000 megacycles with a power input of 2,000 watts to the food.

Although the penetration of microwaves with this equipment is limited at present to a food depth of approximately 2.5 inches, it is of significance that with relatively small quantities of food (2 lb. or less) the temperature of the food may be raised from room temperature or as low as — 10° F. (— 23° C.) to 140° F. (60° C.) in 2 minutes or less, dependent on a number of factors such as weight, thickness, and type of material. Equipment of this type is now manufactured and distributed for use in hotels, restaurants, and similar institutions for the preparation of food for the table.[a]

The significant difference between food products cooked in the radar oven and those cooked by conventional methods is that in the former case no crust or

[a] We are indebted to the Raytheon Manufacturing Company of Waltham, Mass., for the loan of the radar oven equipment used in this research.

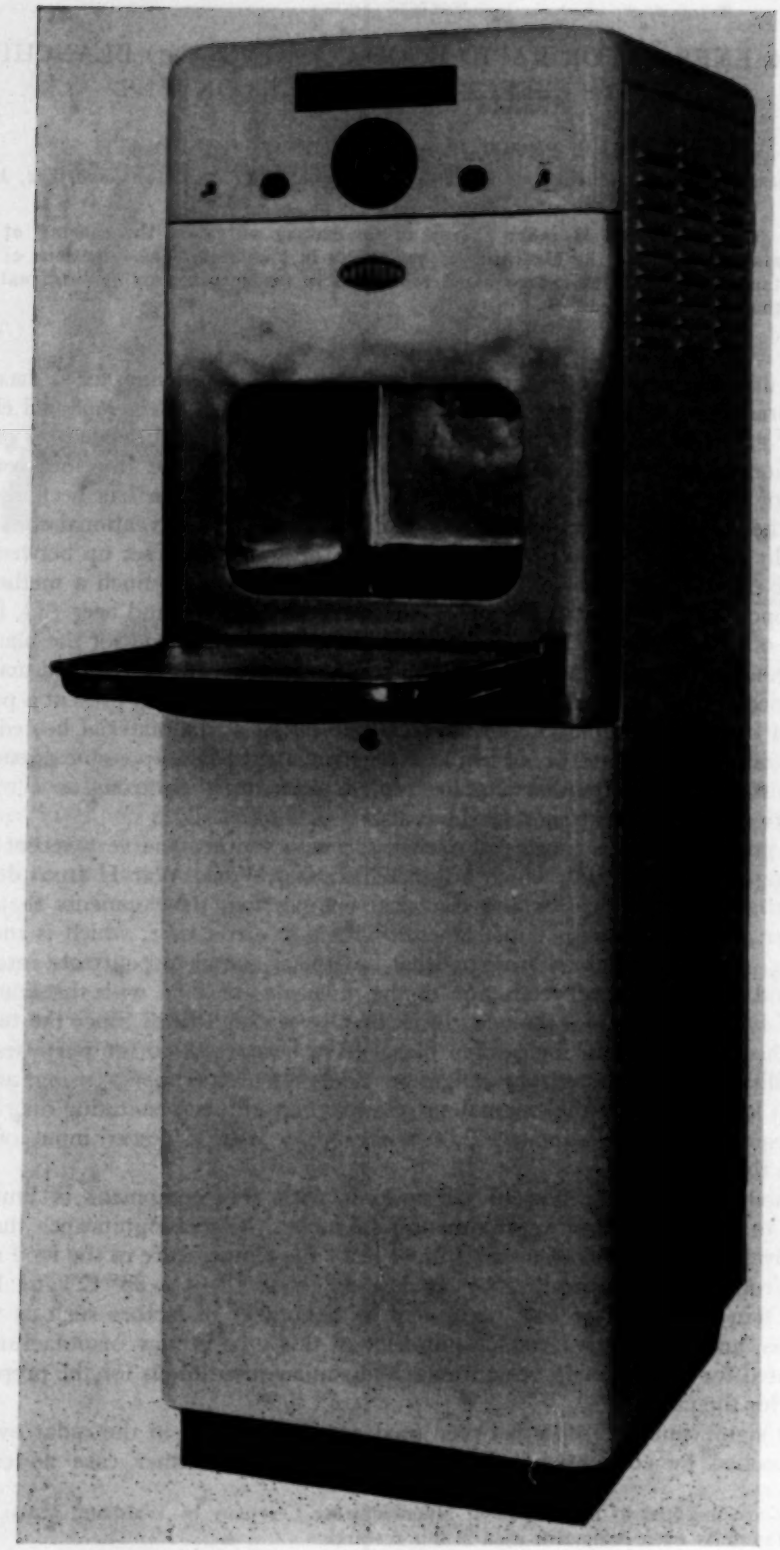

FIG. 1. Photograph of radar oven used.

carbonized surface is formed because the heating is uniform throughout the product. When foods having their normal water content are cooked in the radar oven, heating above the boiling temperature of the mass is impossible as long as water is retained in the food. In this present investigation, comparisons were made of the taste and the appearance of various foods heated in the radar oven and by conventional methods, and special emphasis was placed on an analysis of the vitamin content of the foods thus treated.

Thus far but one published report has come to our attention on the use of microwave treatment of foods, namely, that by Morse and Revercomb *(8)*. Their study, however, dealt with the problems encountered in thawing and heating of frozen precooked meals in a magnetron oscillator having a frequency of 1,050 megacycles and did not include observations on taste, appearance, and vitamin content of the foods.

EXPERIMENTAL

Samples of comminuted meats and of fish were subjected to treatment by 3,000 megacycle radiation, and duplicate samples of these same foods were simultaneously cooked by conventional methods using a gas range. The same procedure was followed with samples of prepared cake mixes, as it was found that this type of radar equipment is advantageous in the almost instantaneous baking of cake mixtures. The heating of vegetable products by microwave treatment also proved to be so rapid that the use of this equipment for the blanching of vegetables previous to freezing was compared with the usual procedures of blanching by boiling water and steam.

With the meats, fish, and prepared cake mixtures determinations were made of the thiamine and the riboflavin contents, and with the vegetables of the ascorbic acid content. The initial and the final vitamin contents were determined in each case. The ascorbic acid content was determined by the Hochberg, Melnick, and Oser method of assay *(7)* for reduced ascorbic acid, after the ascorbic acid was stabilized by blending with four parts of 0.5 per cent oxalic acid. The thiamine content was determined by the thiochrome method and the riboflavin content by the fluorometric method *(1)*. The tests made for inactivation of catalase and peroxidase were essentially those of Proctor *(11)*.

Hamburg. Commercially ground hamburg was purchased on the open market and seasoned with a small amount of salt and pepper. Four small, flat, round hamburg patties weighing 75 g. each were placed in 600-ml. glass beakers (one in each beaker) and cooked in the radar oven for one minute. This was done to recover the components that might be lost by spattering.[b] After the high frequency treatment, the liquid and the solid portions of each hamburg pattie were separated. As preliminary experiments had indicated some variation in the rate of heat rise in various parts of the radar oven, the liquid portions of the four patties were combined in one sample and the solid portions in another sample, and these were analyzed separately for thiamine and riboflavin content. From the same batch of ground raw meat, four more hamburg patties of the same size were made and fried in a skillet in the conventional fashion on a gas plate. Separation of liquid and solid portions was not followed with the gas-cooked samples, as recovery of any spattered components was impossible. The hamburg patties required only 60 seconds heating in the radar oven, whereas the gas-cooked samples required from 5 to 6 minutes to arrive at what was considered a comparably cooked condition. The radar-cooked

[b] In the normal method of cooking hamburgers in the radar oven the hamburg is cooked between the upper and lower halves of the bun, under which circumstances the juice is absorbed by the bun and is ingested.

hamburg patties were heated throughout the meat evenly and, as a result, there were no crusts at the surfaces of the patties. The radar-cooked patties were also better done in the interior than is the case with grilled patties.

Haddock. The haddock samples were cross-section slices or steaks cut from complete fish bought on the open market. The samples were cut to weigh approximately 90 g. each and had an average thickness of 0.75 inch. Four samples of fish were used for the radar treatment and four samples for gas-oven baking. Treatment time was 40 seconds. Twelve minutes were needed to attain a comparably cooked state in a gas oven at 500° F. (260° C.). The procedures for sample handling previous to vitamin assay were similar to those cited for hamburgers. The baked haddock samples had a light crust at the surface. This was not found in the case of the radar-cooked fish, which were cooked evenly throughout. The taste of the radar-cooked fish was the same as that of the baked fish.

Frankforts. Four frankforts, purchased on the open market and weighing approximately 40 g. each, were treated in separate beakers in the radar oven for 30 seconds. Four similar frankforts were grilled in a skillet in the conventional fashion over a gas plate. Each of these groups was then ground thoroughly in a household meat grinder, and representative samples were taken for thiamine and riboflavin analyses. Comparable raw frankforts purchased at the same time were also ground and assayed. The frankforts cooked by radar energy were similar in taste to those cooked by immersion in boiling water. They were not crisp at the surfaces as found in grilled frankforts.

Cakes. Commercially packaged cake mixes (Devil's Food, gingerbread, and white cake mix) were purchased and mixed with the appropriate amounts of water as specified in the instructions on the packages. Several of these mixes, made into batter with water, were placed in glass baking cups for cooking. Four cups were used for each mix. Other batter mixes were made in complete batch cakes and placed in glass baking pans. Samples were then baked in a gas oven maintained at 375° F. (190° C.), and other samples were cooked in the radar heating oven for the optimal times that had been pre-determined to give finished products of the best appearance, texture, and flavor. The samples in the glass cups were radar cooked, one at a time, in sequence for each group of 4 cups. Samples of these cooked products and of unbaked batters were then assayed for thiamine and riboflavin contents. The radar-baked cakes were cooked evenly throughout and differed from cakes baked in the gas oven mainly in that they lacked a crust. Hence the radar oven is recommended for cakes that are normally to be covered with whipped cream or a frosting. A crust may be obtained easily, however, by exposing the upper surface of a radar-baked cake to the heat radiations of a fine-wire heating element for 1 to 1½ minutes.

Vegetables. Market samples of fresh spinach, broccoli, carrots, peas, and green beans were obtained and prepared as follows:

Spinach: Roots removed and spinach thoroughly washed.
Broccoli: Washed and cut into small pieces.
Carrots: Washed and diced.
Peas: Shelled.
Green beans: Washed, snipped, and cross cut.

Samples of these vegetables weighing 100 g. each were subjected to high frequency radiation in the radar equipment for varying periods of time, to find the minimum time needed to inactivate catalase and peroxidase by use of this equipment. These times (see Table 1) were used in all subsequent experiments.

TABLE 1

Optimal Times Needed to Blanch Vegetables in Radar Oven, Boiling Water, and Steam

Vegetable	Optimal Time for Blanching		
	Radar oven	Boiling water*	Steam*
	sec.	*min.*	*min.*
Spinach	20	2.5	3.5
Carrots	25	3.0	3.0
Peas	25	1.0	2.0
Green beans	20	2.0	2.0
Broccoli	30	3.0	4.0

* From Tressler and Evers *(14)*.

Method of blanching vegetables. The method of radar treatment used for blanching was to place 100 g. of each type of vegetable in a non-rigid thermoplastic bag[c] capable of being heat sealed. The bag was suspended in the radar oven equipment from the tip of an inverted glass funnel at a height just sufficient to prevent contact with the base of the heating chamber, to assure most efficient heating. During the radar treatment, steam is evolved in a few seconds. Therefore, the bag could not be sealed until the heating or blanching period was completed. Sealing was accomplished by twisting the end of the bag several times, folding over and tying with a rubber band. Immediately after sealing, the bag and contents were quickly weighed, then dropped into ice-water and cooled. In this manner, all soluble nutrients were retained, as none were dissipated in the cooling water. Other blanching methods used for comparison were the conventional steam and hot water methods. The times used for blanching in these instances were those recommended by Tressler and Evers *(14)* and are also cited in Table 1. Boiling water was used for the hot water blanch and an autoclave for steam blanching with atmospheric steam. Immediately after the hot-water-blanched and steam-blanched vegetables were cooled in ice water, they were weighed and packaged in thermoplastic bags like those described above.

The fresh vegetables and the vegetables blanched by the three methods were then assayed for reduced ascorbic acid. It was noted with materials such as spinach which were blanched in thermoplastic containers that there was considerable moisture present after the radar treatment. As a consequence, after some similarly treated samples were cooled, the solid and the liquid portions of these spinach samples were separated and analyzed.

RESULTS

Hamburg. Reference to Table 2 indicates that radar heating has no appreciable effect on the thiamine or the riboflavin content of hamburg patties. Slight losses in these vitamin contents were observed in hamburg patties cooked on a griddle over gas, losses ascribable in part to spattering of components which could not be recovered. Losses of a similar order would occur in the radar treatment, if the juices were not recovered, but such losses would not occur if hamburg patties were radar cooked within the rolls, as is the customary method.

Haddock. There appears to be an appreciable loss in thiamine content of haddock with both types of cooking, radar and gas oven baking, with a slight advantage apparent in the gas baking method (Table 2). The percentage losses in

[c] We are indebted to the Dewey & Almy Chemical Company of Cambridge, Mass., for the containers used. The bags were approximately 9 x 14 inches.

riboflavin content are somewhat smaller than those for thiamine by both cooking methods and differ from each other to only a slight extent.

Frankfort. With this type of comminuted food the thiamine loss (Table 2) was greater in the gas-grilled sample than in the radar-cooked sample. Negligible changes in riboflavin content occurred with both methods of cooking frankforts.

Cakes. Each of the various types of cake mix, with one exception, was found to lose thiamine during radar cooking, although the magnitude of loss was consistently greater in the cakes baked by the conventional method (Table 3).

TABLE 2

The Retention of Thiamine and Riboflavin in Hamburg, Haddock, and Frankforts Cooked by Radar Emanations and by Gas

Food and method of cooking	Loss of moisture in cooking	Thiamine		Riboflavin	
		Amount*	Retention	Amount*	Retention
	percent	*gamma/g.*	*percent*	*gamma/g.*	*percent*
Hamburg					
As bought	.....	0.82	.....	1.07	.....
Radar cooked†	5.0	0.82	100.0	1.12	100.0
Solid component	.....	0.72	.....	0.950	.....
Juice component	.....	0.10	.....	0.170	.....
Fried	19.8	0.79	96.0	0.940	88.0
Haddock					
As bought	.....	0.52	.....	0.250	.....
Radar cooked†	6.4	0.28	53.6	0.218	87.2
Solid component	.....	0.22	.....	0.148	.....
Juice component	.....	0.06	.....	0.070	.....
Baked	19.2	0.35	67.4	0.230	92.2
Frankforts					
As bought	.....	1.20	.....	1.73	.....
Radar cooked	2.9	0.86	71.8	1.78	100.0
Grilled	2.9	0.69	57.6	1.66	96.0

* Expressed on fresh moisture basis.
† Includes meat plus juice.

TABLE 3

The Retention of Thiamine and Riboflavin in Cake Mixes Baked in the Radar Range and in a Gas Oven

Product and type of oven	Time of baking	Loss of moisture in baking	Thiamine		Riboflavin	
			Amount*	Retention	Amount*	Retention
	min.	*percent*	*gamma/g.*	*percent*	*gamma/g.*	*percent*
Devil's Food "A" †						
Unbaked	.....	.....	0.750	.....	.....	.....
Radar	1 5/6	7.1	0.670	90.0	.....	.....
Gas	25	13.1	0.570	77.0	.....	.....
Devil's Food "B" †						
Unbaked	.....	.....	0.910	.....	0.565	.....
Radar	1 5/6	6.7	0.715	78.6	0.538	96.5
Gas	25	14.4	0.483	53.1	0.566	100.0
Gingerbread "B" †						
Unbaked	.....	.....	1.13	.....	0.605	.....
Radar	1 5/6	8.0	1.04	92.0	0.379	68.0
Gas	25	10.8	1.00	88.6	0.608	100.0
White Cake "A" (Cupcakes)						
Unbaked	.....	.....	0.282	.....	1.686	.....
Radar	1 1/4	8.4	0.290	100.0	1.250	75.0
Gas	20	16.0	0.228	81.1	1.380	82.0

* Expressed on fresh moisture basis.
† Cakes measured 8 (length) by 4¼ (width) by 1½ (depth) inches.

When a different type of commercial gingerbread batter mix was subjected to various heating times in the radar equipment (Table 4), it was found that the interval of heating used for cooking in the radar oven has a considerable influence on the decreases in thiamine experienced. Overcooking for as brief a period as 30 seconds may almost double the loss. An additional period of overcooking of such slight duration may also have a severe effect on the appearance and edibility of the product. Fortunately an accurate means of automatic precision timing for terminating the exposure period is built into the radar equipment used.

TABLE 4

The Retention of Thiamine in Cake Mix—Gingerbread Cupcakes—Baked for Varying Periods of Time in the Radar Oven and Baked for 25 Minutes in a Gas Oven at 375° F.

Time of baking	Type of oven	Loss of moisture in baking	Thiamine	
			Amount*	Retention
min.		*percent*	*gamma/g.*	*percent*
.....	Fresh mix	.....	1.26	.....
1½	Radar	19.0	0.99	77.9
1¼	Radar	15.2	1.03	81.1
1†	Radar	10.8	1.12	87.9
25	Gas	14.8	0.66	52.3

* Expressed on fresh moisture basis.
† Optimal time for baking small cupcakes (75 g.) of this mix.

TABLE 5

Effect of Blanching with Radar Oven, Boiling Water, and Steam, on Ascorbic Acid Content of Vegetables*

Method of blanching	Ascorbic acid in									
	Carrots		Spinach		Peas		Green Beans		Broccoli	
	Amount	Retention	Amount	Retention	Amount	Retention	Amount	Retention	Amount	Retention
	mg./100g.	*percent*	*mg./100g.*	*percent*	*mg./100g.*	*percent*	*mg./100g.*	*percent*	*mg./100g.*	*percent*
Fresh.....	4.42	.....	14.9	.....	18.0	.....	10.0	.....	93.0	.....
Radar.....	4.50	100.0	14.6	98.0	22.0	100.0	10.5	100.0	95.0	100.0
Boiling water...	1.62	36.7	3.5	23.5	16.7	92.8	7.3	80.0	81.4	87.5
Steam.....	3.56	80.4	5.6	37.6	18.1	100.0	9.8	98.0	87.0	93.5

* Expressed on fresh moisture basis.

Vegetables. The effects of blanching with the radar oven, with boiling water, and with steam on the ascorbic acid content of vegetables are tabulated in Table 5 and shown graphically in Figs. 2 and 3. It is apparent that practically no loss was sustained in ascorbic acid content by any of the several vegetables when subjected to radar treatment for the time periods necessary (see Table 1) to raise the temperatures of the vegetables sufficiently to inactive their enzymes. Steam blanching of the same material was far more efficient than hot water in this respect but less efficient than the radar treatment for some commodities, notably spinach and carrots.

A comparison of the ascorbic acid contents of a different 100-g. sample of fresh, unblanched spinach and of a 100-g. sample of radar blanched spinach from the same lot that was separated, after blanching, into its liquid and solid portions before vitamin assay gave the following results:

	Ascorbic acid
Fresh, unblanched spinach	38.20 mg.
Juice, radar blanched	2.13 mg.
Solids, radar blanched	32.38 mg.

This comparison shows that only a small amount of ascorbic acid was contained in the juice, the major portion being in the solids.

A like comparison was made with a similar 100-g. sample of fresh, unblanched spinach and a 100-g. sample of spinach from the same lot blanched in boiling water. In this case vitamin assays were made not only on the water-blanched solids but on the blanching water after used, with the following results:

	Ascorbic acid
Fresh, unblanched spinach	38.20 mg.
Blanching water	28.30 mg.
Solids, water blanched	9.00 mg.

The retention of ascorbic acid in the solids of the radar-blanched spinach was strikingly greater than that in the solids of the water-blanched spinach. Almost all the ascorbic acid apparently lost by spinach solids in the water blanching procedure may be accounted for in the blanching water, which would normally be

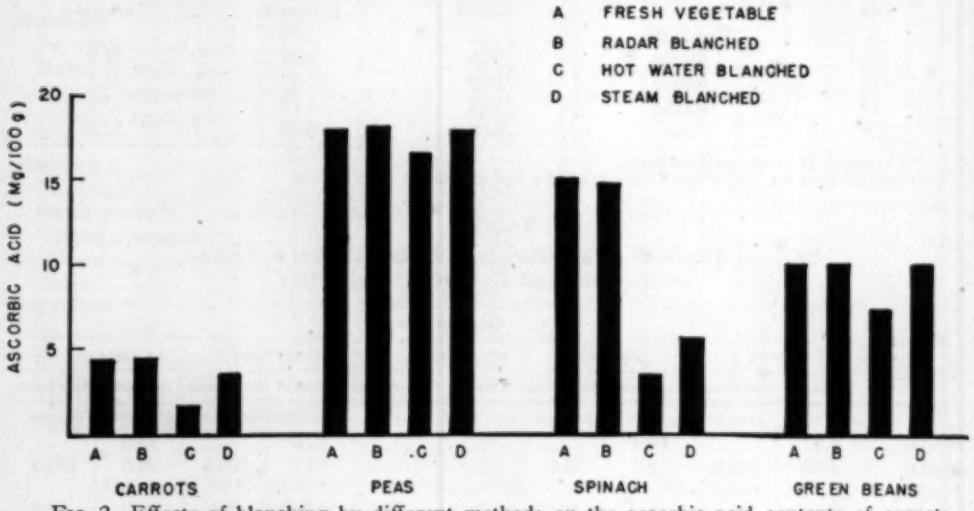

FIG. 2. Effects of blanching by different methods on the ascorbic acid contents of carrots, peas, spinach, and green beans.

discarded. There may also have been a small vitamin loss during the cooling period when the spinach was in contact with ice water. Cooling of the water-blanched spinach in a sealed container rather than by the commonly accepted practices now in use might offer a slight advantage from the standpoint of vitamin conservation. It would seem that the conservation of ascorbic acid in vegetables by radar blanching might have practical advantages in food processing on a large scale, should radar treatment in the form of a continuous line process become a reality—and it is predicted that this may soon be the case.

In the normal methods of blanching corn-on-the-cob, extended steam treatments are necessary. In the cooling operations the soluble sugars may be leached out to a certain extent. To ascertain the applicability of radar treatment to corn-on-the-cob, two ears of corn were placed in a thermoplastic bag and blanched in the radar oven for one minute. The bag was then sealed and cooled by immersion in ice water. The resulting product was found to be completely blanched and of excellent texture and flavor. A very presentable package was also obtained, as the bag shrank tightly around the corn during the radar-oven process. Similar samples were frozen and found very acceptable in later taste tests. No vitamin determinations were made with the corn.

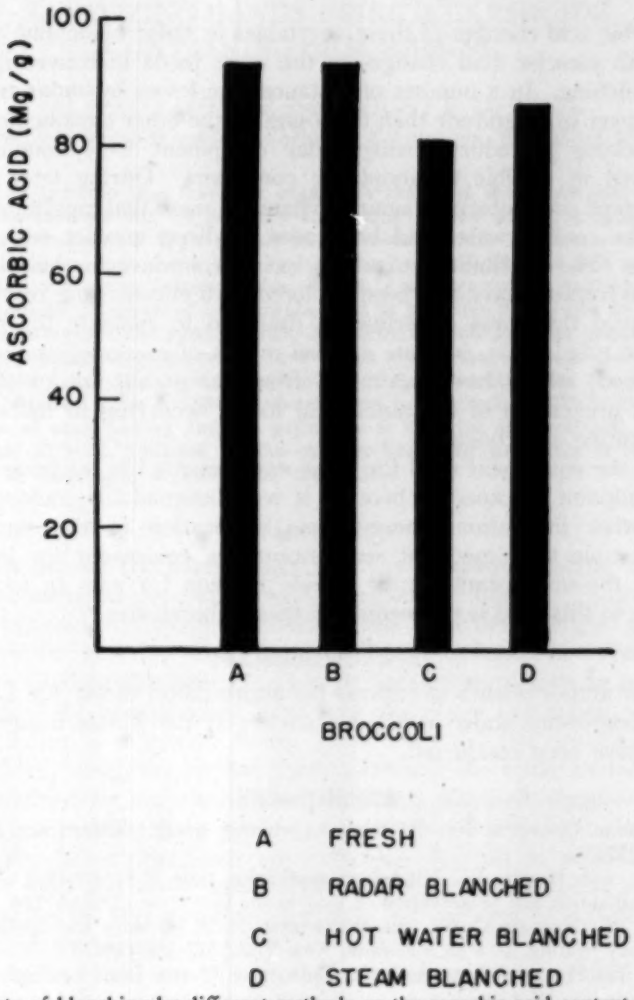

FIG. 3. Effects of blanching by different methods on the ascorbic acid content of broccoli.

SUMMARY AND CONCLUSIONS

An investigation has been made of a number of raw food materials cooked or heated in extremely short periods of time by the internal excitation of the materials through the influence of radar, a magnetron tube operating at a frequency of 3,000 megacycles and having a wave length of 10 cm.

The products investigated included comminuted meats such as hamburg and frankforts, sections of fish (haddock), prepared cake mixes, and fresh vegetables such as peas, carrots, spinach, green beans, broccoli, and corn-on-the-cob.

The optimal periods necessary for proper radar cooking, or the times required for inactivation of the enzymes (blanching) of fresh vegetables were determined. In all cases the optimal period was 30 seconds or less.

The effects of radar treatment for optimal periods on the thiamine, riboflavin, and ascorbic acid contents of the various commodities were determined. These results have been compared with changes in vitamin content occurring in similar samples of raw material cooked or heated by conventional methods such as frying or gas-oven baking.

The ascorbic acid changes of these vegetables in radar blanching have also been compared with ascorbic acid changes of the same foods in conventional steam or hot water blanching. In a number of instances the losses by radar treatment were appreciably lower in magnitude than the losses by the other treatments.

The blanching procedures using radar equipment were conducted on food samples packed in flexible thermoplastic containers. During later cooling these containers served as protection against vitamin losses that might otherwise have occurred if the cooling water had been used in direct contact with the blanched raw materials. The possibilities of using such a container for blanching by radar preliminary to freezing have also been explored with encouraging results.

It is believed that these experiments, designed to evaluate the possibilities of the magnetron tube, radar, indicate a novel means of extremely rapid heating and cooking of food, which has advantages from the standpoint of speed and the standpoint of prevention of the nutritional losses occurring in more conventional methods of heating and cooking.

Although the equipment used for these experiments has, at present, limitations from the standpoint of capacity, because it was designed for cooking purposes in hotels and other institutions, nevertheless application of the same magnetron radiation principle to a modified semi-continuous equipment for line operations may offer in the not distant future a wide horizon for uses in food processing. Further work in this field is proceeding in these laboratories.

ACKNOWLEDGMENT

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SANITIZING HANDS USING A GERMICIDE CONTAINING CHLORAMINE T

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Studies indicate that transient organisms that find their way onto the skin of the human hand can be partially eliminated by the use of a commercially available Chloramine-T type germicide incorporated into a mixture with soap powder. This has been shown both by laboratory experiments and field experience in the poultry dressing industry. Use of such a mixture for the routine washing of the hands by personnel of restaurants, food or beverage plants can be expected to further safeguard the public health. No claim is made that the germicide will sterilize the skin, since this would involve the elimination of both the transient and resident flora. The ease of application of this treatment, its low cost, and apparent freedom from irritation indicate that it is practical. While the use of a mixture of soap powder and the germicide is effective and practical, the successive use of soap, followed by the chlorine-liberating germicide is still more effective in destroying organisms on the hands.

INTRODUCTION

It has been known for many years that the frequent washing of the human hand keeps the bacterial population within reasonable bounds. Further, we know that soap has but minor, if any, germicidal action. It is the detergent action of soap that is important in removing organisms from the outer layers of the skin.

P. B. Price *(2, 3)* and others *(1, 4)* have done much to give us an understanding of the flora of the normal skin. The flora consists of two types, although there is no sharp dividing line between them. First, there are the organisms, known as the transient flora, which are chance contaminants of the outer surface, and which are largely removed by soap and water washing, although usually incompletely. Second, there is a resident flora growing on and, to a very slight extent, growing in the skin. The latter organisms are extremely difficult to remove. Prolonged scrubbing with soap and water using a stiff bristle brush (surgical scrub up) will reduce the number by about one-half for each six minutes of scrubbing, but will not eradicate them completely.

The sterilization of the hand is a complex problem, which to date has not been solved. Interest in this problem has been very active during the war years, and several materials have been suggested for this purpose. These include quaternary ammonium compounds, and bis (2 hydroxy-3, 5, 6, trichlorophenyl) methane. All have failed of achieving sterility of the skin, although all, if properly used, will greatly reduce the bacterial population. From a public health point of view we may assume that the greatest good from hand sanitization will follow when all food handlers include a hand sanitizing treatment whenever they wash their hands. However, to be successful for this purpose the sanitizing agent must be low in cost, colorless, odorless or nearly so, non-irritating, non-toxic, and capable of acting in a comparatively short time.

Existing commercial chlorine-liberating germicides fulfill most of these requirements, and it is surprising that more serious consideration has not been given them for this service. These materials fall into two general classes—the inorganic hypochlorites and the organic chlorine liberating chemicals, of which sodium paratoluene sulfonchloramide (Chloramine T) is an example. A homologue, sodium benzene sulfonchloramide (Chloramine B) is also widely known, and although this compound was not investigated for hand sanitization extensive data from other fields of application show that both chloramines are about equal in germicidal performance.

These organic chloramine type germicides have certain advantages over the hypochlorites for hand sanitization. They are readily and completely soluble, mild in action on the skin, and are dry, stable solids in powder form, lending themselves well to mixing with other dry powders. Thus, they can be dispensed in soap powder dispensers, either in the form of a mixture with soap, or, following a wash with soap, from a second dispenser.

With these thoughts in mind experimental work was undertaken using a commercial germicide* containing 16 percent of Chloramine-T as the active agent, in an effort to learn if this material was capable of effecting a practical reduction in the transient bacterial population of the human hand.

EXPERIMENTAL

For reasons which will be presented later, it was decided not to use the Price technique for evaluating results of hand sanitizing, but rather, to use direct plating of the washed finger and thumb tips. Preliminary experiments indicated that the resident flora of the skin interfered seriously with the procedure of interpreting the results, if nutrient agar or similar general purpose media were used. While the data from these preliminary experiments will not be presented for the sake of brevity, they showed several important findings, and a brief recounting of the techniques and results are in order.

A conventional plunger type soap powder dispenser was used. The instrument was calibrated using both the germicide and a commercial household laundry type soap powder and was found to deliver 1.4 ml. with each stroke. This volume weighed 1.24 grams in the case of the germicide, and 0.67 gram in the case of the soap powder.

From experiments using measured volumes of water, it was determined that the hands of adult males, when wet to the extent achieved by placing them under a flowing tap, carried about 5.0 ml. of water. This volume, of course, will vary, depending upon the size of the hands, and the amount and kind of soil on them.

From the above described measurements, it was calculated that with a volume ratio of 6 to 1 of soap to germicide, one discharge volume used on hands that had been first wet under the tap, would give a solution on the hands of 800 p.p.m. of available chlorine, allowing for a loss of one-seventh of the powder due to manipulation of the hands. Washing operations were timed with a watch, and lasted 30 seconds, followed by a rinse under the tap.

Hardened nutrient agar plates were inoculated after the hand-washing operation by shaking the hands to remove excess water, and lightly touching the tips of the fingers and thumb to the surface. After incubating the plates for 48 hours at 37° C., degrees of growth were arbitrarily indicated as follows:

\+ Light growth, few colonies and these well isolated
\++ Moderate growth, minor or no coalescence of colonies
\+++ Heavy growth, moderate coalescence of colonies
\++++ Very heavy, dense growth

The findings from these preliminary experiments were:

(a) Washed hands regularly showed a density of bacteria as great, and sometimes greater, than unwashed hands when soap only was used.
(b) Washing with a mixture of soap and germicide showed a density of bacteria lower than either the unwashed hand, or the hand washed with soap only.

*"Steri-Chlor," made by Wyandotte Chemicals Corporation, Wyandotte, Michigan.

(c) Washing with soap, rinsing, and then washing with the germicide, was superior to washing with a mixture of soap and germicide.
(d) Including fine sea sand in the soap-germicide mixtures to secure a scrubbing action without resorting to a scrub-brush did not alter the results, and was no better than simple mixtures.
(e) The normal resident flora of the hand which was not greatly reduced in members by these sanitizing treatments interfered greatly in interpreting the results of the various treatments.

In order to circumvent the difficulty of the resident flora, it was decided to use a pure culture of *Escherichia coli* as a test organism, and eosin methylene blue (E. M. B.) agar as the plating medium. This permitted a differentiation of the test organism from common skin organisms. The following experiment is typical of results obtained using *E. coli* as a test organism. The treatment techniques were as follows. Platings of the fingers were made after each of the following numbered steps:

(1) E. M. B. plates were inoculated with the dry unwashed finger tips. This was done to show the presence or absence of *E. coli* at the start of the experiment.
(2) The hands were scrubbed for 10 minutes with a stiff bristle brush and Ivory soap, rinsed, and applied to the plates. This was done to reduce the members of *E. coli* should No. 1 prove to be positive.
(3) The hands were inoculated with a 24 hour lactose broth culture of *E. coli* and rinsed under the flowing tap.
(4) The hands were inoculated with *E. coli* as in No. 3, then washed for 30 seconds with one discharge volume of soap from the dispenser and rinsed.
(5) Same as No. 4 except that one discharge volume of a 1 to 4 ratio of germicide to soap was used.
(6) Same as No. 5, except that we used an equivalent amount of soap alone, washed for 30 seconds, rinsed, and followed this with a wash using an equivalent amount of germicide for 30 seconds. The hands were then rinsed.
(7) Same as No. 6, except that the final water rinse was omitted. The data for two subjects, using the above techniques, are given in Table 1.

TABLE 1

Hand Sanitizing Test Using Escherichia coli and Plating on E. M. B. Agar

Test No.	Treatment of Hands	Subject A		Subject B	
		Left	Right	Left	Right
1	Dry hands, no treatment, no added flora	—	—	—	—
2	Ten-minute scrub-up with soap	—	—	—	—
3	Inoculated and rinsed	++++	++++	++++	++++
4	Inoculated and washed with soap	+++	+++	+++	+++
5	Inoculated and washed with soap plus germicide	++	++	++	++
6	Inoculated and—				
	(a) Washed with soap 30 seconds				
	(b) Washed with germicide 30 seconds	+	—	+	+
	(c) Rinsed				
7	Inoculated and—				
	(a) Washed with soap 30 seconds				
	(b) Washed with germicide 30 seconds	—	—	—	—

This shows that success was attained in ridding the hands of the added organisms when first washed with soap and followed by washing with the germicide, but only partial success after washing with a mixture of soap and germicide, although the reduction was pronounced. Fig. 1 has been made from photographs of plates obtained from this experiment.

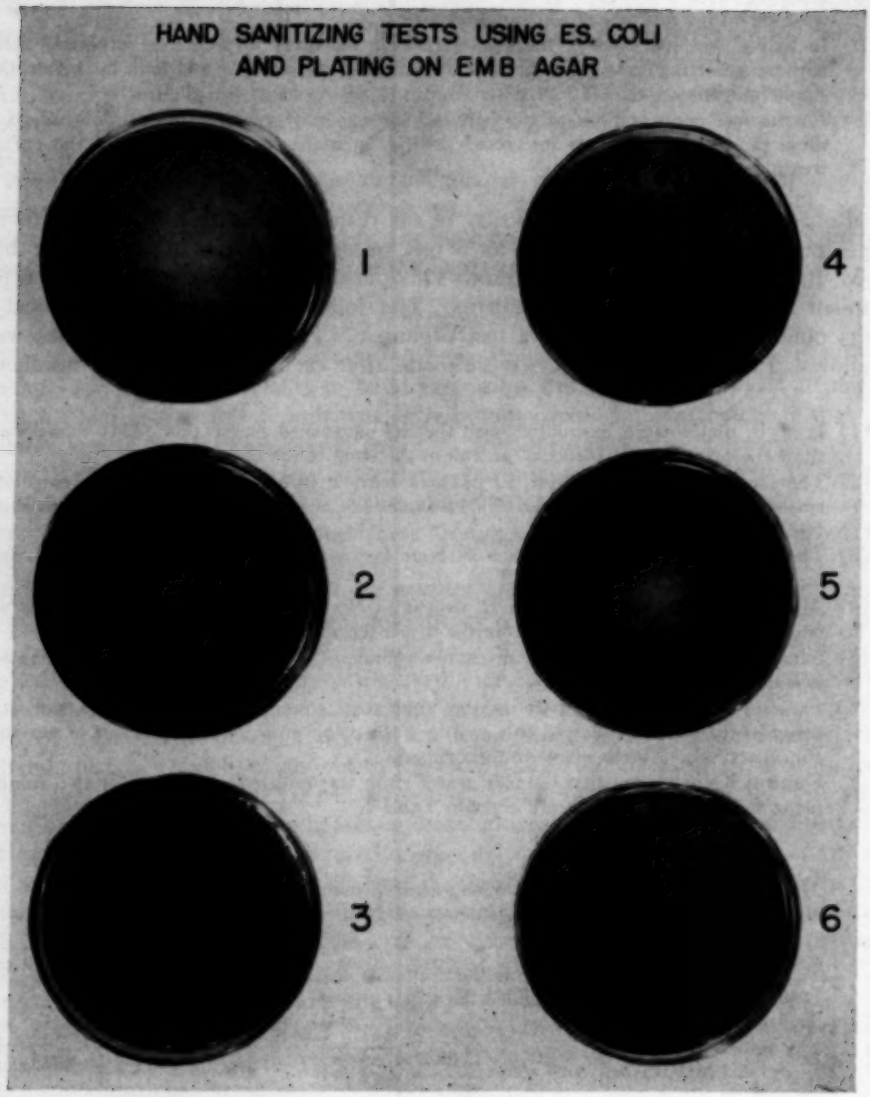

FIG. 1. Photographs of plates obtained by touching the tips of the fingers and thumb to E. M. B. agar after various washing techniques. Plates incubated 48 hours at 37° C.

1. Uninoculated hand after a 10-minute scrub-up with soap and water, then rinsed under a flowing tap. Note absence of *E. coli* colonies.
2. Hand inoculated with a culture of *E. coli* and then rinsed under a flowing tap.
3. Hand inoculated as in No. 2, washed with soap only for 30 seconds, and rinsed under the flowing tap.
4. Hand inoculated as in No. 2, then washed for 30 seconds with a 4 to 1 ratio of soap to germicide mixture, and rinsed under the flowing tap.
5. Hand inoculated as in No. 2, then washed with soap powder alone for 30 seconds, rinsed, and then washed with the germicide for 30 seconds, and finally rinsed under the flowing tap. The quantities of soap and germicide were equal to those used in No. 4 and to the soap used in No. 3.
6. Same as No. 5 except that the final rinse under the flowing tap was omitted thereby giving the germicide slightly longer than 30 seconds in which to act.

FIELD TESTS IN THE POULTRY DRESSING INDUSTRY

Field tests in the poultry dressing industry were undertaken to evaluate practical results when using a mixture of granular soap and the Chloramine-T containing germicide. Because of the nature of this industry the ratio of soap to germicide was 3 to 1 by volume. Some tests were included wherein germicidal treatment followed simple washing with soap. Arrangements were made with officials of the Board of Health of a large city to cooperate in this work. A member of the poultry inspection staff was assigned to the study, and to select the establishments for the tests. The establishments ranged from two story modern clean plants that eviscerate, to small less sanitary plants that only killed and picked fowl, but did not eviscerate.

From 3 to 5 subjects were used from each of 6 establishments, and these included both white and colored workmen. The workmen went about their regular tasks until called upon for the tests. The workmen were directed to shake any loose soil or debris from their hands, and to then lightly touch the surface of the test plates with the tips of their fingers and thumb. Next, the subjects were directed to wash their hands with the soap or germicidal mixture provided. These materials were made available from soap powder dispensers. No time limit was set on the length of time used by the subjects in washing their hands, nor on the amount of soap powder used—the men were told simply to wash their hands in their normal and natural way. After the hands were washed, they were rinsed under flowing tap water, and the hands shaken to remove excess water but not dried on a towel. All of the subjects used either two or three strokes of the plunger rod of the dispenser, with most using three strokes. Most of the subjects washed their hands for from 20 to 25 seconds, but a few washed for no more than 15 seconds.

Finally the men inoculated fresh plates by gently touching the agar surface with the damp finger tips. One hand was used to inoculate a nutrient agar plate and the other an E. M. B. agar plate. The inoculated plates were returned to the laboratory, incubated for 48 hours at 37° C., and read.

The data for these field tests are given in Table 2.

The results here are very clear cut. In every case the coliform index (E. M. B. agar) of the hand was reduced by using the germicidal mixture from a reading of four plus, to either 1 or 2 plus. Soap alone reduced the coliform index to 2 or 3 plus, and in most cases to 3 plus. In those tests where the double treatment was used, (soap first, followed by the germicide) the index was reduced to 1 plus.

Considering the results of the nutrient agar plate, one finds that soap washing reduces the population on the hands very little. The germicidal mixture does somewhat better, and the double treatment is still more successful. It must be remembered, however, that nutrient agar is a good culture medium for the normally harmless resident flora of the skin, and the difficulties encountered in the previously reported laboratory studies apply to these field studies. It is felt that the coliform index is a measure of ability of a germicidal detergent or treatment to deal with transient organisms and is of far greater importance than the total organism index obtained with nutrient agar. The nutrient agar plate findings are included in the table for the sole purpose of showing the wide differences obtained with the two agars.

DISCUSSION

The quantitative methods of Price, involving a series of sterile pans containing sterile rinse water which is later plated, were not used in this work for several reasons. This technique finds its greatest usefulness in problems dealing with the resident flora, and not the transient flora with which we were concerned. Further, the Price technique is time-consuming, and is not adaptable to field studies.

TABLE 2

Field Tests in the Poultry Dressing Industry

Establishment	Subject	Material Used for Washing the Hands	Organism Index After Washing [a]	
			E. M. B. Agar (Coliforms)	Nutr. Agar
A	1	Germicidal Mixture	+	+++
	2	Germicidal Mixture	++	+++
	3	Soap	+++	+++
B	4	Germicidal Mixture	++	++++
	5	Germicidal Mixture	+	++++
	6	Soap	+++	++++
C	7	Germicidal Mixture	+	
	8	Germicidal Mixture	++	
	9	Soap	++	Not
	10	Soap	+++	Run
	11	Soap	+++	
D	12	Germicidal Mixture	+	+++
	13	Germicidal Mixture	+	++++
	14	Soap followed by germicide	+	++
	15	Soap followed by germicide	+	++
E	16	Germicidal Mixture	+	
	17	Germicidal Mixture	+	Not
	18	Germicidal Mixture	+	Run
F	19	Germicidal Mixture	++	++
	20	Soap	++	+++
	21	Soap followed by germicide	+	++

[a] With but one exeeption the organism index on all subjects, using both agars, was four plus (++++) before the hands were washed.

Our work indicates that a commercially available germicide containing Chloramine-T as the active agent can be successfully used for sanitizing the hands, and when used for this purpose will reduce the members of an added flora far below what soap and water will accomplish. No claim is made that this material will sterilize the hands.

It should be understood clearly that in sanitizing the hand it is the transient flora that should be removed. Any treatment that materially reduces the resident flora is apt to be very harsh to the skin or very toxic. In our experiments with the Chloramine-T containing germicide we encountered no evidence of irritation to the skin or allergies of our subjects. However, we were dealing with a relatively small number of people and these were using the germicide for only a few days at a time. If used by a large group for a long time irritations or allergies may develop in a few individuals.

When chlorine-liberating products are used for sanitizing the hands a slight odor remains. The chloramines leave less odor than do the hypochlorites, and the odor is far less pronounced when the germicide is used as a mixture with soap than when used alone, following a soap wash.

Although our data indicate that the efficiency of the chlorine germicide is lowered by using it in a mixture with soap, this method would be preferred by most people. When properly performed, the single treatment with the mixture gives a very worth-while reduction in the bacterial population of the hand. This was shown both in the laboratory experiments and in the field trials.

CONCLUSIONS

1. Chloramine-T containing germicides can be used successfully for sanitizing the hands to destroy chance organisms that find their way onto the skin. This is not to be confused with sterilizing the skin.
2. Washing with soap and water has been shown to reduce the number of organisms adhering to the skin of artificially inoculated hands but slightly, but a wash with a mixture of soap and a Chloramine-T containing germicide will reduce the numbers very materially. An even more successful type of hand treatment consists of a separate wash with soap, followed by a wash with the germicide.
3. Field tests in the poultry dressing industry have yielded data which confirm the laboratory findings.
4. The ease of application of this treatment, its low cost, availability of the germicide, and apparent freedom from irritation indicate that it is practical.
5. Chlorine-liberating germicides will leave a slight residual odor on the hands. The odor is minimal and hardly noticeable when the germicide is used with soap as a mixture.

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THE EFFECT OF BENZOIC ACIDS ON SPOILAGE ORGANISMS[a]

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Data presented on the phenol coefficients of eleven benzoic acids obtained with lactobacilli show that, in general, the values are higher than with the usual test organisms.

INTRODUCTION

In a previous investigation, the authors *(3)* studied the germicidal properties of certain benzoic acids when *Eberthella typhi* and *Staphylococcus aureus* were used as the test organisms. The present investigation is a study of the effect of these benzoic acids on organisms found in spoiled foods. Four organisms, representing as many different groups of spoilage organisms, were used in the present experiments. These organisms belong to the groups of bacteria isolated from spoiled tomato products by Pederson and Breed *(1)*.

STUDY OF GERMICIDAL POWER

The method used for the determination of germicidal activity was the one modified by the United States Food and Drug Administration and termed the F. D. A. method *(2)*, with the exception that the following organisms were substituted for *E. typhi* and *S. aureus* as test organisms: *Lactobacillus lycopersici, Lactobacillus mannitopoeus, Lactobacillus pentoaceticus,* and *Lactobacillus plantarum*. The relative germicidal power of each compound is expressed by its phenol coefficient. Each organism was transferred every 30 days to fresh agar slants. Nutrient broth for growing the test organisms and for their subculturing was prepared according to the following formula: Liebig's beef extract (Lemco), 5 g.; peptone (Armour's) 10 g.; sodium chloride, 5 g.; distilled water to make 1,000 cc.; pH adjusted to approximately 6.8.

Before the test organisms were used in a determination, their resistance was built up to uniformity by five serial daily transfers. The cultures which were employed in each test were between 22 and 26 hours old. Saturated solutions of the chemicals to be tested were prepared and preserved at 20° C. If these solutions were capable of killing the test organisms in 10 minutes, more dilute solutions were prepared.

A total of 30 seeding tubes was employed in each determination; 27 containing 5.0 cc portions of various dilutions of a benzoic acid stock solution and three tubes containing dilutions of phenol. These seeding tubes were placed in a thermostat at a temperature between 19 and 21° C. After the temperature of the contents of each tube had become constant, one-half cc of a uniform mixture of the test organism-culture was added to each of the 30 seeding tubes. After periods of 5, 10 and 15 minutes, a subculture was made from each of the seeding tubes into properly numbered tubes of fresh nutrient broth. This procedure was accomplished by means of a loop needle (No. 23 B. and S. gage platinum wire), having an inside diameter of 4.0 mm. Transfers were made at 10-second intervals. When the process of subculturing was completed, the tubes of freshly inoculated broth were incubated at

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37° C. for 48 hours. The phenol coefficient was calculated by dividing the highest dilution of the chemical compound showing growth in five minutes but not in 10 minutes by the dilution of phenol showing the same conditions.

Table 1 gives the data obtained for the benzoic acids studied when they were tested with each of the four spoilage bacteria. In addition, coefficients previously determined with *E. typhi* and *S. aureus* are given for comparison.

TABLE 1

The Phenol Coefficients for the Selected Acids With Certain Organisms Isolated From Spoiled Foods

Name of acid	*E. typhi*	*S. aureus*	*Lactobacillus lycopersici*	*Lactobacillus mannitopoeus*	*Lactobacillus pentoaceticus*	*Lactobacillus plantarum*
Benzoic	5.3	0.0	5.0	5.5	0.0	5.5
o-Chlorobenzoic	7.8	0.0	10.0	10.0	0.0	7.0
o-Hydroxybenzoic	10.7	10.7	14.0	16.0	13.0	13.0
m-Hydroxybenzoic	2.7	2.1	2.2	1.8	2.0	2.8
o-Nitrobenzoic	8.5	6.0	10.0	10.0	7.5	7.0
m-Nitrobenzoic	6.0	6.7	7.0	10.0	6.5	8.0
2, 4-Dinitrobenzoic	7.7	6.8	10.0	10.0	9.0	7.0
3, 5-Dinitrosalicylic	7.3	7.7	8.0	8.5	12.0	10.0
3-Nitrosalicylic	7.3	9.0	13.0	13.0	12.0	13.0
beta-Resorcylic	5.2	4.0	6.0	7.0	5.5	10.0
2, 4, 6,-Trinitrobenzoic	5.5	3.9	7.0	8.5	4.6	5.0

DISCUSSION

A comparison of the results shown in Table 1 reveals that the phenol coefficients obtained with the food spoilage organisms are higher generally than those obtained with *E. typhi* and *S. aureus*.

The acid showing the greatest activity of the group of benzoic acids against the spoilage organisms was *o*-hydroxybenzoic. The phenol coefficients for this acid with the spoilage organisms are from 2 to 5 points higher than those obtained against the pathogenic organisms.

The *o*-chlorobenzoic acid shows a fair degree of activity against *Lactobacillus lycopersici* and *Lactobacillus mannitopoeus*, the phenol coefficients being 10.0 with each of these organisms. Contrary to the general statement made above, this acid yielded a lower coefficient against *Lactobacillus plantarum* than it did against *E. typhi*, and demonstrated no activity against *Lactobacillus pentoaceticus*.

With the spoilage organisms 2, 4-dinitrobenzoic, *o*-nitrobenzoic, 3, 5-dinitrosalicylic, *m*-nitrobenzoic, 2, 4, 6-trinitrobenzoic, and beta resorcylic acids occupy intermediate positions in the table, and their phenol coefficients lie within a very close range of each other. All the phenol coefficients (averages) are higher than those obtained for these acids against the pathogenic organisms, with the exception of *m*-hydroxybenzoic acid.

Benzoic acid demonstrates about the same germicidal activity against three of the food spoilage organisms as it did against *E. typhi*. With *Lactobacillus pentoaceticus*, the saturated solution of benzoic acid failed to kill the organism in fifteen minutes; therefore, a zero coefficient is recorded. The latter valuation agrees with that obtained for benzoic acid against *S. aureus*. All of the acids studied, with the exception of *m*-hydroxybenzoic acid, showed a greater efficiency in preventing the activity of food spoilage organisms than did benzoic acid.

CONCLUSIONS

1. The killing power of eleven benzoic acids was determined with four organisms isolated from spoiled food products.

2. In general, the phenol coefficients obtained with the food spoilage bacteria were higher than those obtained with the pathogenic bacteria.

3. The *o*-hydroxybenzoic, 3-nitrosalicylic, and 3, 5-dinitrosalicylic acids were found to be the strongest in germicidal activity against the spoilage organisms.

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BACTERIOLOGICAL CONSIDERATIONS RELATING TO PROCESS EVALUATION

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A critical analysis is made of the methods of process evaluation, based on the logarithmic nature of the death of bacteria. It is shown that mechanism of heat transfer within the food container must receive consideration if greatest accuracy in process evaluation is to be attained. A method is presented for ascertaining the location in the food container where probability of bacterial survival is greatest. The analysis considering both logarithmic order of death of bacteria and mechanism of heat transfer within the container shows that lethality of heat treatment at the point of greatest temperature lag in the container is often not a true criterion of the sterilizing capacity of a thermal process.

The primary object of thermal processing a food is to free the food of microorganisms which are considered undesirable because of their capacity to endanger the health of the food consumer or because of their capacity to cause deterioration of the food to such an extent as to render it unfit for consumption. Whether the thermal process is to destroy all or a fraction of the number of microorganisms present, virtually the same problems exist with respect to predicting the required severity of an adequate and desirable process. Chief among these problems at present is that of accurately predicting the effect of any given quantity of heat on bacteria which, if present in the product, must be destroyed.

The General Method, for calculation and evaluation of thermal processes for foods, described by Bigelow, et al. *(5)* is a graphical procedure for integrating the lethal effects of various time-temperature relationships existent at the point of greatest temperature lag in a container of food during process. The procedures developed by Ball *(1, 2)* are mathematical methods for integrating the lethal effects of time-temperature relationships. These methods, especially the more versatile mathematical methods, have been used extensively in the canning industry. Several simplifications and improvements in the original methods have been suggested *(11, 15, 16)*. None of the simplifications or improvements suggested has involved alteration of the original concepts on which the methods, both graphical and mathematical, were based. However one of the concepts, that regarding the influence of heat on bacteria, on which the methods were based is not wholly compatible with present knowledge concerning destruction of bacteria by heat. This original concept can best be visualized by reviewing the definitions of certain terms, or their equivalents, used in both the graphical and mathematical procedures for evaluating thermal processes for foods. The terms and their definitions are as follows:

F—A symbol which represents the number of minutes required to destroy an organism at 121.1° C. (250° F.), assuming instantaneous heating and cooling of the medium surrounding the organism.

U—A symbol which represents the number of minutes required to destroy an organism at retort temperature — $U = FF_1$.

F_1—A symbol which represents the number of minutes required to destroy an organism at retort temperature when F is equal to one or, which represents a value equal to $\frac{U}{F}$.

z—A symbol which represents the slope of the thermal death time curve for an organism, and defined as the number of degrees Fahrenheit required for the thermal death time curve to traverse one logarithmic cycle—the thermal death time curve being obtained by plotting on semilog paper temperature in the direction of abscissae, and time required to destroy the organism in the direction of ordinates.

It will be noted that each of the above definitions is based on the concept that time-temperature relationships exist which can account for destruction of all cells (vegetative or spore form) of any given organism in the food product concerned. Though it has been recognized for many years that the number of bacterial cells (or spores) per unit volume of product is directly related to the severity of the process required for sterilization, no alteration in the mathematical or graphical procedures for process evaluation, to account for the effect of numbers of bacteria, has been suggested. Further, there has been very little consistency in the treatment of this factor by those employing these methods of evaluation. For these reasons and because of inherent practical implications involved, the following thoughts are offered concerning a well founded concept of the influence of heat on bacteria and concerning modifications of present methods of process evaluation in light of this newer concept.

DESTRUCTION OF BACTERIA BY HEAT

The literature is replete with evidence to support the belief that death of bacteria is logarithmic in nature—that is, that the normal rate of destruction curve for bacteria is a straight line on semilog paper when the number of surviving bacteria (or spores) per unit of material is plotted in the direction of ordinates and time of heating is plotted in the direction of abscissae *(4, 9, 14, 18)*. Exceptions to this normal order of death have been noted *(12, 13)*, but for the purpose of analyzing problems relating to processing of canned foods it would seem justifiable on the basis of available evidence to assume that the logarithmic order of death generally obtains. In other words, the normal rate of destruction of bacteria by heat may be mathematically described by the same formula as used to describe the rate of a unimolecular chemical reaction, namely, $k = \frac{2.303}{t} \log \frac{C_o}{C}$, in which C_o is the concentration (bacteria per unit volume) at the beginning of the reaction when time is zero, and C is the concentration after time t has elapsed. In this equation log C plotted against time gives a straight line. A typical rate of destruction curve plotted on semilogarithmic coordinates is shown in Figure 1. The symbol Z (Zeta) has been suggested *(4)* to represent the slope value of the rate of destruction curve—Z being defined as the number of minutes required for the curve to traverse one logarithmic cycle.

Assuming instantaneous heating and cooling, and considering Z as the unit of time, it may be said that 90 percent of the organisms are destroyed during each unit of heating time. For example, starting with 1,000,000 organisms per container of food, the rate of destruction per container may be pictured as follows:

Time in Terms of Z Units	No. of Organisms Surviving
0Z	1,000,000
1Z	100,000
2Z	10,000
3Z	1,000
4Z	100
5Z	10
6Z	1
7Z	0.1
8Z	0.01

It should be noted that Z is not constant except for a given set of conditions. Its value will depend on temperature applied, kind of bacteria to be destroyed, nature of the medium in which the bacteria are suspended, and possibly other factors.

Z must be determined from rate of destruction data and is used to express time here as a matter of convenience only.

A fraction of a spore surviving must be interpreted as one spore surviving in one of a number of containers equal to the reciprocal of the fraction. In other words 0.01 spore surviving simply means one spore surviving per 100 containers of product. It might be argued that this condition refers to partial destruction of the last surviving organism and therefore sterility. Such an interpretation cannot be

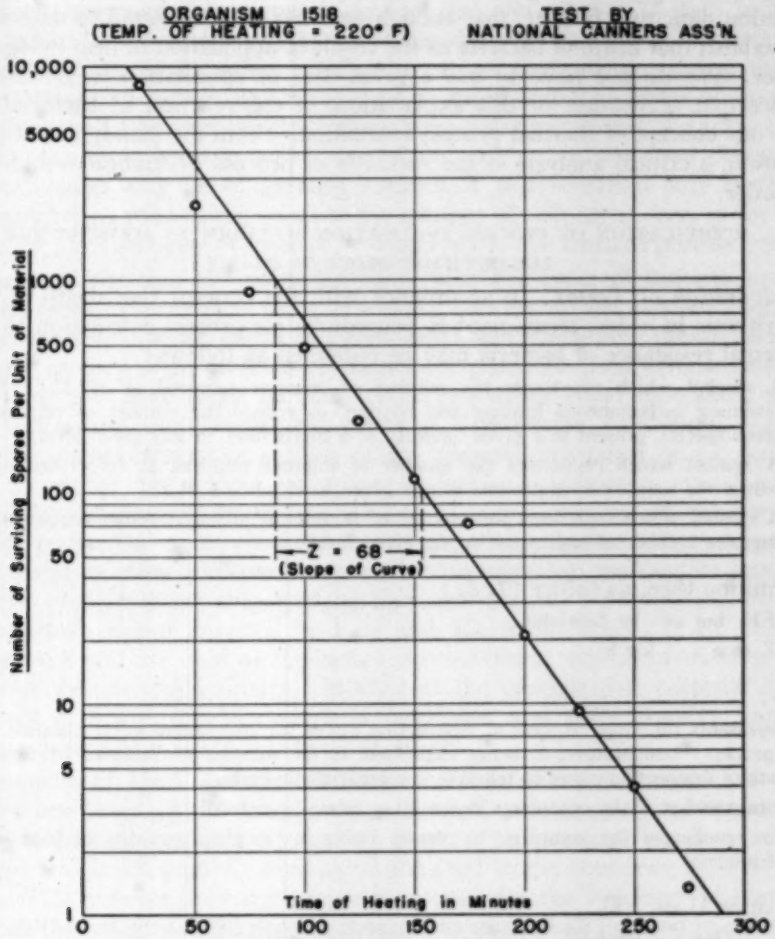

FIG. 1 RATE-OF-DESTRUCTION CURVE ON SEMI-LOGARITHMIC COORDINATES (ZETA = 68)—TAKEN FROM BALL (1943)

correct if death of the spores follows the law governing the rate of a unimolecular chemical reaction. If we accept the explanation that bacterial death caused by a given agent is logarithmic in order, we must also accept the contention that absolute destruction by this agent of an infinite number of bacteria is impossible. For further discussion bearing on this point consult Rahn *(14)* and McCulloch *(9)*.

Ball *(4)* very ably discusses the relationship of rate of destruction curves to thermal death time curves. He presents formulae for establishing "phantom" thermal death time curves from rate of destruction data. The "phantom" thermal death

time curve is described as a curve with direction, but not position—that is, position with respect to destruction time or end-point of destruction. In other words "phantom" thermal death time curves establish the z values, but not the "end-points of destruction" for organisms to be destroyed. Williams, et al. *(19)* described a special apparatus for determining rate of destruction, by heat, of bacteria in foods. Figure 1 shows a rate of destruction curve constructed from data collected by use of this apparatus and the techniques described.

Suffice it to say at this point that techniques are available for obtaining rate of destruction data, and further, that enough data has been collected to date to pretty well establish that death of bacteria as the result of application of heat is logarithmic in order. We do not have to use a great deal of speculation in describing the influence that acceptance of this explanation, of the reaction of bacteria to heat, has on our concept of thermal process evaluation. From the standpoint of practical application, a critical analysis of the methods of process evaluation would seem to be in order.

MODIFICATION OF PROCESS EVALUATION METHODS TO ACCOUNT FOR LOGARITHMIC ORDER OF DEATH

Redefinition of Terms. In accordance with the concept that death of bacteria is logarithmic in order, terms used in procedures for process calculation to account for thermal resistance of bacteria may be redefined as follows:

F—A symbol which represents the number of minutes required at 121.1° C. (250° F.), assuming instantaneous heating and cooling, to reduce the number of organisms of a given species, present in a given quantity of a given food, to any given level.

F_1—A symbol which represents the number of minutes required at retort temperature to reduce the number of organisms to any given level when $F = 1$.

U—A symbol which represents the number of minutes required at retort temperature to reduce the number of organisms to any given level.

By definition then, as before *(1, 2)*:

$U = FF_1$, but also by definition:

$U = Z\ (\log a - \log b)$

Where:

Z—represents the slope of rate of destruction curve for the organism in question at retort (process) temperature, Z being expressed as the number of minutes required for the rate of destruction curve to traverse one logarithmic cycle.

a = total number of the organisms in the given quantity of food.

b = the number of the organisms to remain viable in the given quantity of food at the end of process.

Then, since $U = FF_1$

$$F = Z\,\frac{(\log a - \log b)}{F_1}$$

The mathematical expression

$$F_1 = \log^{-1}\frac{250 - RT}{z}$$

may still be employed providing that the value of z is established from rate of destruction data.

The terms, as defined in this way would be subject to variation in value with variation in number of bacteria per unit quantity of product because the severity of a process required to reduce the probability of survival of bacteria to any given

extent will depend on the initial number of bacteria per unit quantity of product. In accordance with the principle that death of bacteria is logarithmic in order, it follows that, other things being equal, the greater the number of bacteria per unit quantity of product the more severe will be the thermal process necessary to reduce the number to any given level. Number as used here does not refer to the total number of cells of all types of bacteria present; but to the number of cells, or spores, of the type or types which the process is designed to destroy. Ordinarily, many types of bacteria occur in foods prior to their being heat processed. The order of resistance of many of these types is so low that the number of such bacteria is readily reduced to insignificance by processes designed to destroy bacteria of the more resistant types. In other words, the rate of destruction, during the more severe processes, of certain types would be so rapid that the chance of survival of any of them would be virtually nil if there were millions present per gram of food. However, the same bacteria which are of no concern in processes designed for food sterilization may be of greatest concern if pasteurization only is the aim. Hence, number as used above refers to the number of cells, or spores, of the species which is the most resistant of those to be destroyed by the thermal process employed.

Because of the lack of knowledge concerning the types of bacteria occurring in various foods prior to their being processed, concerning the concentration of the more resistant types which might be encountered, and concerning thermal resistance of bacteria as they occur in foods, F values for processes used commercially have for the most part been based on commercial processing experience and results of studies concerning the thermal resistance of *Clostridium botulinum*. Esty and Meyer *(6)* made exhaustive studies of the thermal resistance of *Cl. botulinum* spores suspended in neutral phosphate solutions. Maximum resistance was observed for suspensions containing billions of spores per ml. of solution. The maximum resistance values observed were higher than those which have generally been observed by other workers for spores of this organism, perhaps because of the high spore concentrations employed by Esty and Meyer. Nevertheless, the maximum resistance values reported by Esty and Meyer for spores of *Cl. botulinum* have been and still are used as the basis for establishing safe commercial processes throughout the canning industry. In view of the concept that bacterial death is logarithmic in order, this procedure is justifiable, and quite possibly imperative to the establishment of safe commercial processes.

Mechanism of Heat Transfer in Canned Foods. Present methods of process evaluation are based on the concept that a thermal process adequate to accomplish sterilization of the food at the point of greatest temperature lag in a container during process is adequate to sterilize all the food in the container *(1, 2, 4, 5, 11, 15, 16)*. This concept does not properly account for the influence of number of bacteria on the lethality of the process required to sterilize all the food in a container.

Jackson *(7)* on the basis of data accumulated over a number of years covering heat penetration tests in a large number of food products, classified the products according to the mechanism of heat transfer within the food container. Six main classes of products are listed, ranging from those which heat by rapid convection throughout the process to those which heat by conduction throughout the process. For the sake of simplicity, discussion here will be confined to the two classes representing the two extremes with respect to mechanism of heat transfer, namely, foods which heat primarily by convection and foods which heat primarily by conduction.

Jackson *(7)* and Jackson and Olson *(8)* reported results of a series of studies concerning the mechanism of heat transfer in bentonite suspensions during process

in No. 2 (307 x 409) and No. 10 (603 x 700) cans. A suspension of five percent bentonite in water gave heat penetration curves quite typical of those usually obtained for certain food products which heat by conduction. A suspension of one percent bentonite gave curves typical of those for certain convection-heating products. A suspension of 3.25 percent bentonite gave broken heating curves, indicating convection heating changing to conduction heating during the process. The latter suspension need not be discussed here beyond saying that the nature of heat transfer in it is similar to the nature of that observed for certain foods and ultimately should receive consideration, with respect to process evaluation, similar to that given the other types of heating.

On the basis of results of these studies with bentonite, mechanisms of heat transfer may be described in general as they relate to calculating adequate processes for food sterilization.

Conduction-Heating Products. Products heating by conduction, if the container is stationary, do not move within the container during process. During heating, heat from the surrounding medium (usually steam or hot water) is transferred to the outermost layer of food in the container, thence inward toward the center of the food mass without any of the food, and bacteria in the food, changing location within the container. When a container of food is placed in a heating medium such as steam under pressure it may be quite safely assumed that a very thin layer of food next to the container wall assumes the temperature of the steam almost instantaneously. Heat is then transferred inward toward the center of the food mass from all points at the container wall. During the initial phase of heating there is a constant temperature portion of food near the center of the container. The temperature of the food near the container wall rises during this lag period. Subsequent to the lag period the temperature from the center to the can wall rises on a smooth curve. If heating is allowed to continue long enough, the entire contents will eventually reach the temperature of the surrounding steam; however, the last portion of food to reach this temperature will be that at the geometric center of the container (the point of slowest heating).

If at the end of any given heating time, the container is plunged into cooling water (say at a temperature of 70° F.) heat transfer within the container is reversed in direction and the contents cool until equilibrium is reached with the surrounding medium. Because temperature rise during heating and temperature drop during cooling are logarithmic in order, cooling to a non-lethal temperature is accomplished in considerably less time than is required to heat the food, from the lowest temperature which is lethal, to the highest temperature attained during process. Therefore, even though the temperature drops less rapidly at the center than at other points in the container during cooling, there is a small volume of food at the center which receives a less severe heat treatment than any other food in the container. Then it may be said that the severity of heat treatment increases progressively from the center, in any direction, to the wall of the container.

If we visualize a series of cylindrical containers ranging in size from one the size of the food container to one the size of a short piece of thin pencil lead we can picture this decrease in severity of heat treatment from outside to center of the mass of food. If the containers are considered to decrease in size progressively in accordance with a uniform decrease in length and diameter we may picture them being placed one inside the other from largest to smallest such that the geometric center of each imaginary cylindrical container is common with geometric center of the real container. It can be shown that the surface area of each of these imaginary containers would represent a number of bacteria, bearing the same relation to the

number of bacteria represented by the surface area of the real container as the surface area of the imaginary container bears to the surface area of the real container. Also the surface area of one imaginary container would bear the same relation to the surface area of another as the number of bacteria at the surface of one bears to the number of bacteria at the surface of the other. The decrease in severity of heat treatment from the outside to center of the real container is also related to the decrease in surface area of the imaginary cylindrical containers; and therefore, it is related to the decrease in number of bacteria from outside to center of the real container. It should be noted here that the relationships pictured are not exact; but, their divergence from the more complicated relationships which truly exist during process is believed to be so small that errors induced from use of the assumed relationships in methods of process evaluation would be negligible. The true relationships could be visualized by picturing the imaginary containers gradually changing from cylindrical in shape to ellipsoidal or spherical in shape from outside to center of the real container. Differences in container size and shape would influence these relationships, but the total influence of all these factors is believed minor and justifiably neglected in the following considerations.

Location in Container Where Probability of Survival is Greatest. Assume that a conduction heating food is placed in a No. 10 (603 x 700) can and the mechanism of heat transfer within this food during process will be identical with that described by Jackson and Olson *(8)* for a five percent bentonite suspension. Assume further that this can of food contains 10,000 spores of *Cl. botulinum* uniformly distributed in the food mass. At what location in the container would the probability of spore survival be greatest? What would be the F value of the heat treatment at the geometric center of the container when the probability of survival is one in one billion, or some other given value, at the location where probability of survival is greatest? Probability of survival as used here and elsewhere in this paper refers to the probability of one spore surviving in some given number of containers or at some given location in some given number of containers. For example, a probability of survival of one in one billion for some given location in the container refers to a condition wherein there should be only one spore surviving at this location in only one of every one billion containers.

For a condition of 10,000 spores per No. 10 can of food, there should be one spore per approximately 0.3 cc. of product. Also, there would be approximately 1,215 spores in a layer of food, 0.3 cm. in depth, next to the can wall; 860 spores in a layer of equal depth next to the wall of an imaginary container 5 inches in diameter and 6 inches high; 567 spores in a similar layer next to the wall of an imaginary container 4 inches in diameter and 5 inches high; 347 in the corresponding layer for an imaginary container 3 inches in diameter and 4 inches high; 162 in the corresponding layer for an imaginary container 2 inches in diameter and 3 inches high; and, 50 in the corresponding layer for an imaginary container 1 inch in diameter and 2 inches high. Assuming one spore to be located at the geometric center and plotting the number of spores at the surface of the various containers against the radius of the corresponding containers a spore distribution curve is obtained describing the increase in number of spores from geometric center to wall of the No. 10 can for a condition of 10,000 spores distributed uniformly in the food mass (Figure 2).

The severity of heat treatments to reduce to some given level the number of spores at the different locations in the container may be calculated. Taking the

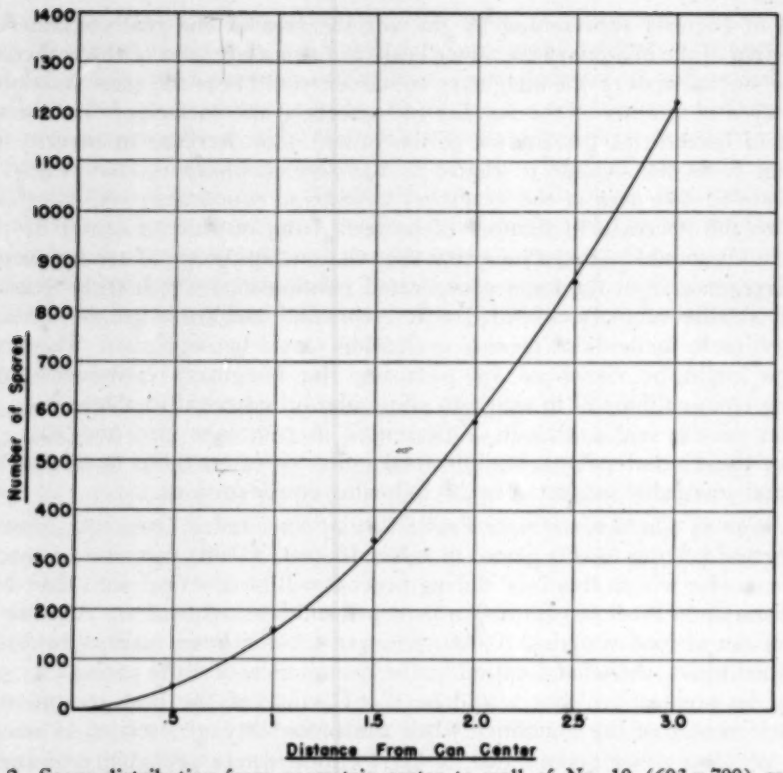

FIG. 2. Spore distribution from geometric center to wall of No. 10 (603 x 700) can, when 10,000 spores are distributed uniformly in food mass. Distances from can center (radii of imaginary cylinders of food) plotted against number of spores lying at surface of respective imaginary cylinders—see text.

values computed to represent the number of spores at the center, at the surface of each of the imaginary containers, and at the surface of the real container, we find heat treatments having the following F values required to reduce the number at each location to .000000001 spore.

Initial Number of Spores	F Value Required
1 (center)	1.953
50 (0.5 inch = radius of container)	2.322
162 (1.0 inch = radius of container)	2.433
347 (1.5 inch = radius of container)	2.504
567 (2.0 inch = radius of container)	2.550
860 (2.5 inch = radius of container)	2.589
1,215 (3.0 inch = radius of container)	2.622

These F values were calculated using $Z = 0.217$ for slope of rate destruction curve for spores of *Cl. botulinum* heated at 250° F., and using the following equations:

$$U = Z\ (\log a - \log b)$$

$$F = \frac{U}{F_1}$$

$$F_1 = \log^{-1} \frac{250 - RT}{z}$$

RT was taken as 250° F. The value of z was assumed to be 18° though its value does not alter the above calculated values of F. The value 0.217 used for Z is about average for values computed from published work *(6, 17)*.

If the F values listed above as required for the different numbers of spores are plotted on the linear scale against the respective numbers of spores on the log scale a straight line curve is obtained. This may be termed the F requirement curve (Curve No. 1, Figure 5) for *Cl. botulinum* spores. In practice, the F requirement curve should be established from resistance values obtained for botulinum spores suspended in the food for which a process is to be calculated.

Heat penetration curves representing heat treatments at various points in the food from the geometric center to the can wall may be estimated from the temperature distribution curves, reported by Jackson and Olson *(8)*, for a five percent bentonite suspension (see Figure 3). On the basis of these heat penetration curves, F values for the heat treatments at various points in the container may be calculated. Assuming that one single spore would be located at the point representing the geometric center of the container, the minimum F value required to reduce the probability of survival to one in one billion at this point should equal 1.95. The time requirement (191 minutes) for a thermal process (RT = 250° F.) was therefore calculated which would result in this F value at the center of the container. (A z value of 18° was assumed to represent the slope of the thermal death time curves for spores of both *Cl. botulinum* and P. A. 3679.) F values for heat treatments at other points various distances from the center were then calculated for the process of 191 minutes in length. The F value of the heat treatment for food next to the can wall was assumed to be 191. Then each F value calculated was for food at a point some given distance from the geometric center of the container and lying in a horizontal imaginary plane bisecting the container midway between the top and bottom. Each point was visualized as also lying at the surface of a cylinder of food the radius of which would equal the distance from the center to the respective point. The height of each cylinder was considered to be as much less than the height of the container as the diameter of the cylinder was less than the diameter of the container. By plotting the number of spores at the surface of each imaginary cylinder against the F value for any point at the surface of each cylinder, an F distribution curve was obtained which described the F value of the heat treatment to which any given number of spores was subjected.

The F distribution curve plotted on the same coordinates as the F requirement curve for 10,000 spores uniformly distributed in the food mass determines the location in the container where probability of spore survival is greatest. Figure 5 shows the F requirement curve (Curve No. 1) for 10,000 spores of *Cl. botulinum* as they are distributed in the food and the F distribution curve (Curve No. 2) for a hypothetical conduction-heating food which heats during process similarly as did the five percent bentonite suspension studied by Jackson and Olson *(8)*. With regard to F requirement and F distribution curves so plotted, it may be said that, if and only if all points on the F distribution curve fall on or above all points on the F requirement curve, the probability of spores surviving at any point in the container is as low as or lower than the probability of survival for which the F requirement curve was established (one in one billion for the F requirement curve in Figure 5). It may be noted that, in this case, the probability (one in one billion) would be greatest at the geometric center.

Convection-Heating Products. Foods which heat by convection exhibit much more rapid heating than do foods which heat by conduction. In the case of convection heating, transfer of heat in the food mass is aided by product movement within

the container. For a condition of ideal convection heating, temperatures throughout the container of food during process would be identical at all times. Then it may be said that for ideal convection heating, heat treatments at all points throughout the container would have identical lethality (F) values. Though such an ideal condition of heating is probably never realized, it is obvious that movement of product within the container during heating to any great extent would result in more nearly uniform heating. How nearly ideal heating would be approached would depend, other things being equal, on the extent of product movement, and therefore, indirectly on the nature of the product being heated.

In their studies with one percent bentonite suspensions, Jackson and Olson *(8)* determined temperature distribution curves for the product during heating in No. 10 (603 x 700) cans. Figure 4 shows a series of curves representing temperatures across a central horizontal plane in the No. 10 can. The curves represent temperature distribution at the various designated minutes during process at a retort temperature of 250° F. Estimating values from these curves, an F distribution curve was established for this convection-heating product on the basis of considerations identical with those on which establishment of the F distribution curve for the conduction-heating product (5% bentonite) was based. This curve (Curve No. 3) appears in Figure 5. Observing Figure 5, it will be noted that a considerable portion of curve No. 3 lies below curve No. 1, the F requirement curve for *Cl. botulinum*. This indicates that the process (8.9 minutes at 250° F.) calculated to give an F value of 1.95 at the center of the container is inadequate to reduce the probability of survival to one in one billion at all locations in the container. It may be noted that the probability of survival is greatest at locations quite remote from the geometric center (in this case, at the surface of an imaginary cylinder the radius of which is about 2.5 inches and the geometric center of which is common with the geometric center of the real container). Curve No. 4 is curve No. 3 moved upward in the direction of ordinates to a position at which all points on the curve lie on or above the F requirement curve. The F value (2.50) indicated by the intersection of curve No. 4 and the Y-axis represents the F value which would be obtained at the center of the container for a process adequate to reduce the probability of survival of *Cl. botulinum* spores to one in one billion at the location in the container where probability of survival is greatest. Curve No. 5 is the F distribution curve for a product which would heat ideally by convection. It may be noted that the F value indicated by the intersection of this curve and the Y-axis is equal to 2.62, or that value required to reduce the probability of survival to one in one billion at the location where probability of survival is greatest.

It may be said that foods in No. 10 cans exhibiting temperature distribution patterns during process identical with those of one and five percent bentonite suspensions would require thermal processes adequate to give food at the center of the containers heat treatments having the following F values, if the probability of survival at all locations in the containers is to be one in one billion or less.

Conduction-heating product	1.95
Convection-heating product	2.50

This is considering 10,000 spores of *Cl. botulinum,* of the assumed resistance, are present per container.

Influence of Resistance of Organism to be Destroyed. The magnitude of the difference in F values required, at the center of the container for conduction and convection-heating products, to accomplish comparable reduction in number of

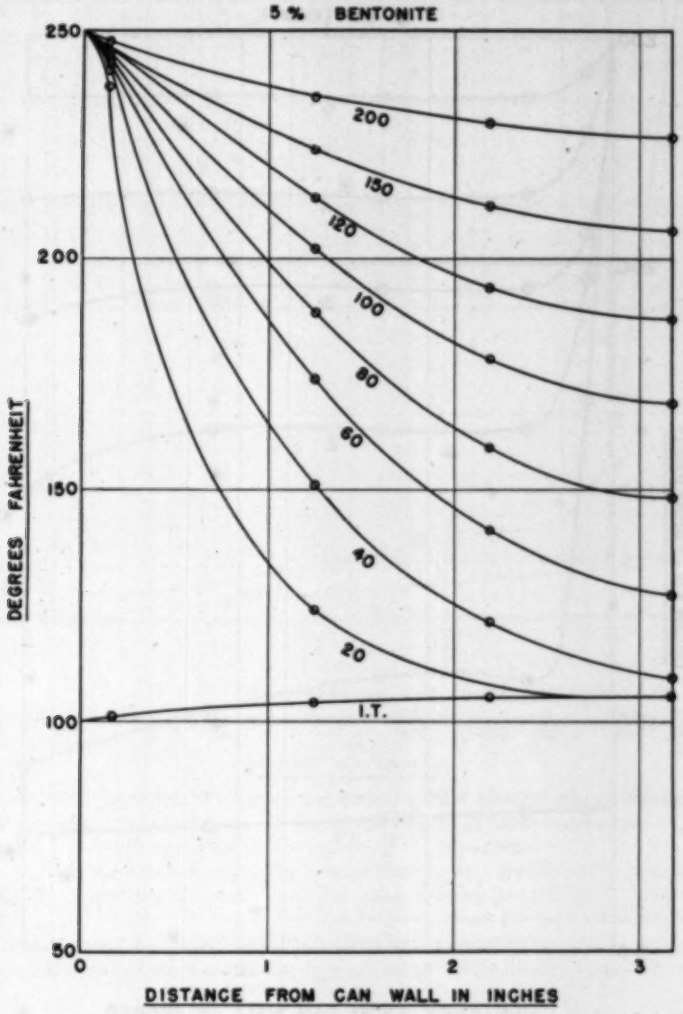

FIG. 3. Temperature-distribution pattern across central horizontal plane in No. 10 can. (The curves represent temperature distribution at various designated minutes during the process.) Taken from Jackson and Olson *(8)*.

viable organisms present should logically be influenced by the resistance of the organism concerned. The relative magnitude of the influence may be pictured by comparing Figures 5 and 6. Curves in Figure 6 were constructed in the same manner as were the curves in Figure 5. The F values for the F requirement curve were determined for the putrefactive anaerobe 3679* by use of the following values in calculations.

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*Non-toxic putrefactive anaerobe designated by National Canners Association as No. 3679.

$Z = 1.0$

$z = 18.0$

End-point of survival = .000000001 spore.

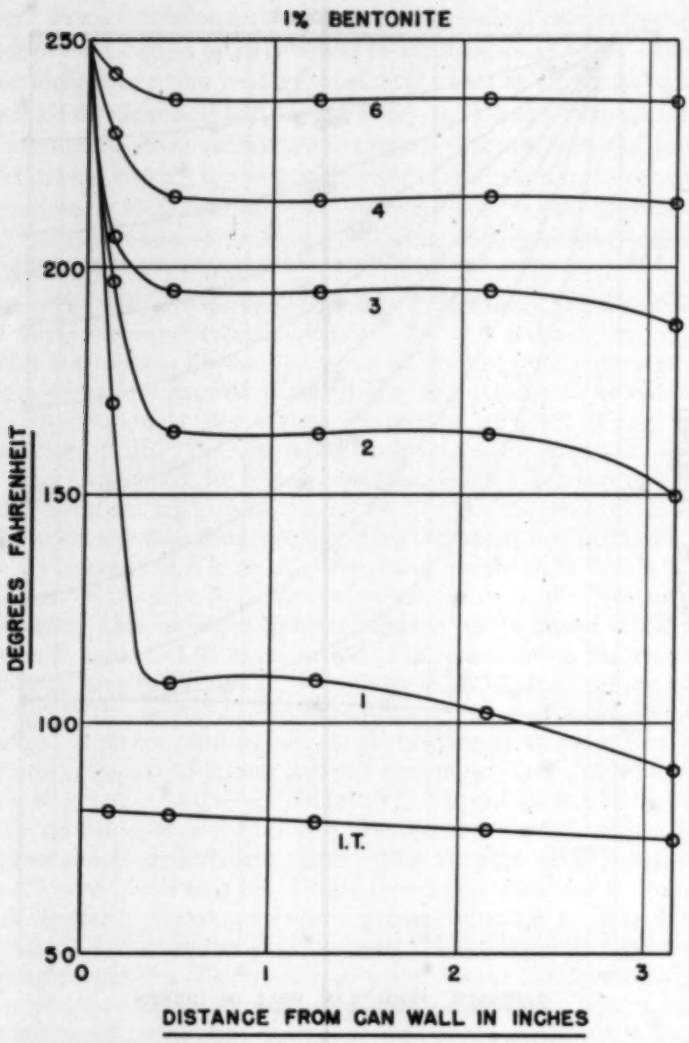

FIG. 4. Temperature-distribution pattern across central horizontal plane in No. 10 can. (The curves represent temperature distribution at various designated minutes during the process.) Taken from Jackson and Olson *(8)*.

F values required therefore were determined to be as follows:

Number of Spores	F Value
1	9
50	10.7
162	11.21
347	11.54
567	11.75
860	11.93
1,215	12.08

Curve No. 1 (Figure 6) is the F requirement curve for spores of P. A. 3679. Curve No. 2 is the F distribution curve for the conduction-heating product. Since a considerable portion of this curve lies below the F requirement curve, it is obvious

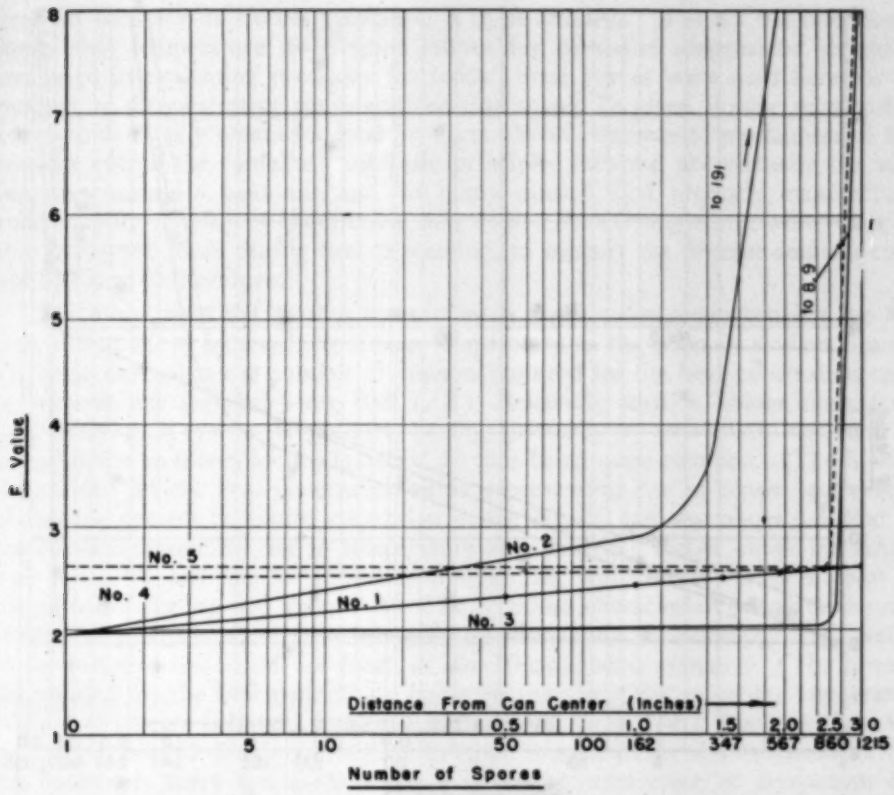

FIG. 5. Graphical depiction of relative capacities of heat treatments, at different locations in the container, to reduce the number of *Cl. botulinum* spores at these locations:

Curve No. 1—F requirement curve for spores of Cl. botulinum.
Curve No. 2—F distribution curve for conduction-heating product (5% bentonite in water).
Curve No. 3—F distribution curve for convection-heating product (1% bentonite in water).
Curve No. 4—F distribution curve for convection-heating product when probability of survival is one in one billion or less at all locations in container.
Curve No. 5—F distribution curve for product which heats ideally by convection.

that, in this case, a process adequate to accomplish the desired survival probability (one in one billion) at the center of the container would not be adequate to accomplish this result at all points in the container. It may be noted that the probability of survival is greatest at locations quite remote from the center (at the surface of an imaginary cylinder the radius of which is approximately one inch and the geometric center of which is common with the geometric center of the real container). Curve No. 3 is obtained by shifting curve No. 2 upward until all points lie on or above the F requirement curve. Curve No. 3 intersects the Y-axis at the point representing an F value of 9.30. Therefore, a process adequate to reduce the probability of survival at all locations in the container to one in one billion or less would result in a heat treatment, at the center of the container, having an F value of 9.30.

Curves No. 4 and No. 5 are similar curves constructed for heating relationships characterizing the one percent bentonite suspension (convection-heating). Curve No. 5 intersects the Y-axis at the point representing an F value of 11.81. An adequate process in this case then would result in a heat treatment, at the center of the container, having an F value of 11.81. Curve No. 6 is the theoretical F distribu-

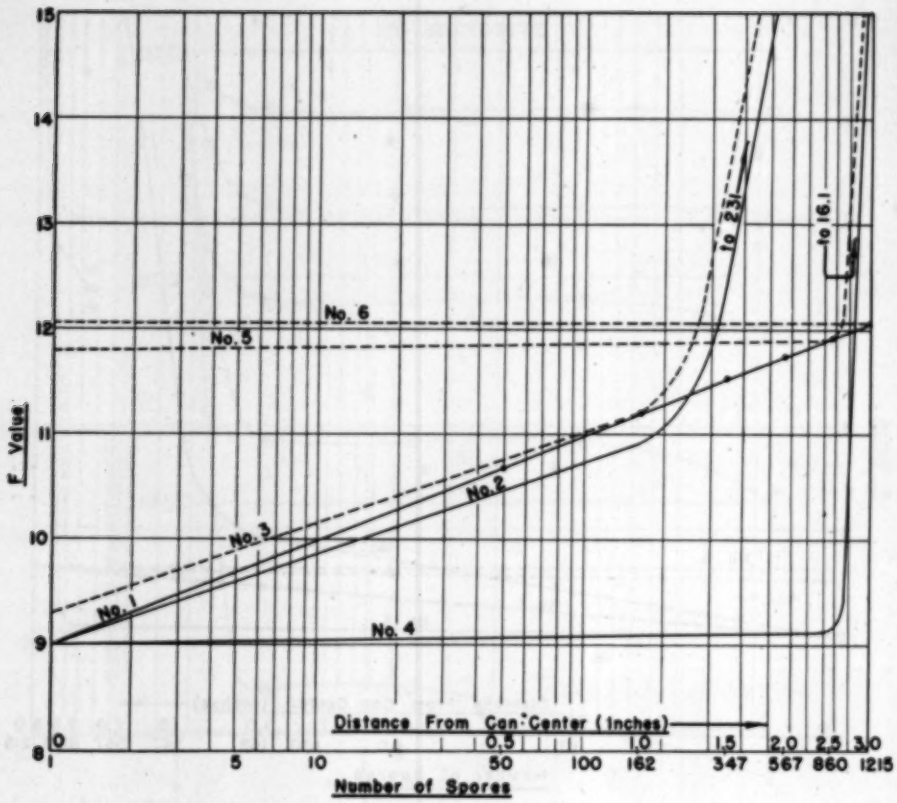

FIG. 6. Graphical depiction of relative capacities of heat treatments, at different locations in the container, to reduce the number of P.A 3679 spores at these locations:

Curve No. 1—F requirement curve for spores of P. A. 3679.

Curve No. 2—F distribution curve for conduction-heating product (5% bentonite in water).

Curve No. 3—F distribution curve for conduction-heating product when probability of survival is one in one billion or less at all locations in container.

Curve No. 4—F distribution curve for convection-heating product (1% bentonite in water).

Curve No. 5—F distribution curve for convection-heating product when probability of survival is one in one billion or less at all locations in container.

Curve No. 6—F distribution curve for product which heats ideally by convection.

tion curve required of a product which heats purely by convection, if probability of survival is reduced to one in one billion or less at all locations in the container.

Based on the values assumed and estimated, processes required to give the desired reduction in survival probability of spores of *Cl. botulinum* and P. A. 3679 at the location where probability of survival is greatest may be specified as follows:

Organism	F Value for Heat Treatment at Center of Container		
	Conduction	Convection	Ideal Convection
Cl. botulinum	1.95	2.50	2.62
P. A. 3679	9.30	11.81	12.08

DISCUSSION

The above considerations, concerning the influence of mechanism of heat transfer and the order of bacterial death on F values required for thermal processes for foods, have been presented in evidence that these factors must be considered if

greatest accuracy in process evaluation is to be attained. It is not the intention to imply that temperature distribution curves for bentonite suspensions should be employed in evaluating processes for foods. Such curves were used here for the purpose of demonstrating considerations that should be given similar relationships which undoubtedly obtain for food products. With reference to mechanism of heat transfer within the container, the basic principles involved are virtually the same for suspensions of bentonite and for many canned food products manufactured commercially. Sufficient quantitative information, concerning temperature distribution in canned foods during heat processing, to support the present analysis could not be found in literature.

The more rapid the heating the smaller is the f_h value characterizing the heat penetration curve representing rise in temperature at the point of slowest heating. (f_h being defined as the number of minutes required for the heat penetration curve to traverse one log cycle—see Ball *1, 2.*) Relatively small f_h values characterize heat penetration curves for products heating primarily by convection, values in the range of five to fifteen for foods in No. 10 cans being quite common. (The f_h value determined for the heat penetration curve representing rise in center temperature of the one percent bentonite suspension in the No. 10 can was about 4.3, that for the curve representing rise in temperature at a point 1.5 inches above the bottom was about 4.8, and that for the curve representing temperature rise at a point 1.5 inches below the top was about 4.0). The f_h values characterizing heat penetration curves for products which heat primarily by conduction are relatively large, values in the range of 150 to 200 for foods in No. 10 cans being common. (The f_h value determined for the heat penetration curve representing rise in center temperature of the five percent bentonite in the No. 10 can was about 174.) Between these two rather well defined classes of foods, with respect to mechanism of heat transfer within the container, there are foods which heat by an admixture of convection and conduction.

A method has been presented for ascertaining the location in the container where probability of bacterial survival is greatest and for arriving at processes which will reduce the probability of survival at this location to any desired level. To arrive at an exact method of process evaluation which will determine the probability of survival in the entire container of food will require a great deal of information concerning temperature distribution in many foods during process. The influence of container size, temperature of processing, etc. on temperature distribution in the container will have to be studied thoroughly. That information of this nature is not available at present is undoubtedly due to the fact that its importance in process evaluation has not been realized heretofore. However, the logarithmic order of death and mechanisms of heat transfer within the container would seem to have been accounted for, to an extent at least, in commercial processing of foods.

Theory and Practice. In January 1930 the National Canners Association issued a bulletin (26-L) titled, "Processes for Non-Acid Canned Foods in Metal Containers." The sixth edition of this bulletin appeared in 1946. Processes recommended in the bulletin have been arrived at through consideration of scientific data and information which major food packing industries have gained by experience. Many processes suggested are more severe than those which have generally been considered necessary to safeguard against botulism; the severity of these processes has for the most part been dictated by commercial experience.

Though the processes listed in Bulletin 26-L are given in terms of times and temperatures for the different products in various sized cans, F values may be calculated, from heat penetration and bacteriological data, and assigned to these

processes. If the z is assumed to be 18°, the F values are designated as F_o values to describe this special condition. This is a convenient assumption to make for the purpose at hand. Two groups of products may be chosen, one representing products which heat primarily by conduction and the other representing products which heat primarily by convection. Table 1 lists six products of each type and the approximate F_o values calculated for the processes recommended for processing the foods in No. 2 and No. 10 cans. Most of the processes for which the approximate F_o values are listed in Table 1, appear in Bulletin 26-L; but for the purpose of completeness, a few were selected from other reliable sources as representative of those which are being used successfully by industry in general. No attempt was made to select only those products the processes for which would support the contentions made here; but rather to select products which it was thought would exhibit similar influences on bacterial resistance even though some heat by convection and some by conduction. Other products could be added to the list, but in reviewing the processes employed for most all low-acid foods it was found that processes given those products listed in Table 1 were sufficiently representative to give a true picture of the point in question. It would be expected that exceptions could be found, but the general picture must be considered rather than exceptions in this case.

TABLE 1

Approximate F_o Values of Processes Used in Industry

Conduction heating			Convection heating		
Product	Approx. F_o value		Product	Approx. F_o value	
	No. 2	No. 10		No. 2	No. 10
Corn (cream style)	5.00	2.50	Corn (whole kernel) in brine	9.00	14.50
Pumpkin or squash	2.25	2.00	Carrots and peas	12.00	16.00
Sweet potatoes (solid pack)	3.50	3.00	Peas	8.00	11.00
Sweet potatoes (syrup pack)	3.00	3.00	Beans (green & wax) brine packed	3.50	6.00
Hash (corned beef, roast beef, and ham)	5.00	5.00	Beans (shelled type, succulent)	11.00	18.00
Spaghetti and meat balls	5.50	5.50	Onions in brine	4.00	7.00
Averages	4.04	3.50	Averages	8.25	12.08

With reference to the F_o values listed in Table 1 for the various products, obvious questions immediately present themselves. It is very doubtful if the differences in severity of processes, indicated by the table, for conduction- and convection-heating products, can be explained on the basis that different bacteria occur in the two types of products, or that the same bacteria are consistently more resistant in products which heat by convection. If so, how can the fact be explained that more severe processes are considered necessary for the convection-heating products in No. 10 cans than are considered necessary for these same products in No. 2 cans? In general, the differences noted are logically explained by considerations discussed above, namely, that bacteria die according to the logarithmic order and that convection-heating results in a larger percentage of the product in the container receiving a uniform or nearly uniform heat treatment of the order of that received by food at the point of greatest temperature lag in the container.

Product Agitation During Process. Upon inspection of Figures 5 and 6 it becomes obvious that, especially in the case of conduction-heating products, food next to the container wall and for a considerable distance toward the center receives heat treatments far more severe than would be necessary to accomplish the same reduction in number of bacteria as is accomplished by an adequate heat treatment at the center of the container. Many foods which heat almost entirely by conduction, and many others which heat partially by conduction when not agitated during processing, will heat almost entirely by convection when sufficiently agitated. Agitation of product therefore should result in less food in the container being over-processed. For this reason, interest in agitation of product during process is now increasing rapidly.

In establishing process specifications for food which is agitated during process full consideration should be given to the influence of temperature distribution in the container on the F value required of the process. By agitation it should be possible to shorten considerably the time required at a given temperature to accomplish sterilization of the product. However, the F value required of the heat treatment at the geometric center of the container would, on the basis of considerations discussed above, have to be somewhat higher. F values of processes comparable in sterilizing capacity to those employed for identical product not agitated during process could be established through studies relating to temperature distribution in the container during process.

High-Temperature Short-Time Processes. Ball *(3)* makes the following statements concerning the relation of processing temperature, heat penetration, and quality:

"Foods that have a high rate of heat penetration, whether it be produced by convection currents in the food or by agitation of the food during heating, will usually have better quality after processing if they are sterilized at temperatures in the higher range, e. g., above 121.1° C. (250° F.), than they will if sterilized at a lower temperature. Conversely, articles having slow heat penetration will usually have better quality after processing if they are sterilized at a temperature below 121.1° C. Furthermore, foods having rapid heat penetration will usually have better quality after being sterilized at a high temperature than will foods having slow heat penetration after being sterilized at a low temperature."

As pointed out by Ball, these facts led to the conclusion that, by increasing the rate of heat penetration into a food that is impaired in quality by the ordinary sterilizing process, and by raising the processing temperature, improvement in quality of the finished product would be attained. During the past twenty years there has been a rapidly growing interest in high-temperature short-time sterilization of foods. Numerous patents have been issued covering various methods and equipment for accomplishing this type of processing of many different foods (see Ball, *3)*.

In the determination of process specification for these high-short sterilization methods, the fact that more nearly uniform heating of the product is being accomplished during process should be fully considered. Though quality improvement is attainable for many foods processed in this manner, it would be reasonable to expect that somewhat higher F values would be required for sterilization than are required of processes characterized by slower rates of heating.

SUMMARY AND CONCLUSIONS

It is proposed that the logarithmic order of death of bacteria receive serious consideration in procedures for establishing adequate and desirable thermal processes for foods. This order of death has been well substantiated by many independent studies by various investigators.

Formulae have been proposed which modify present mathematical methods to account for the logarithmic order of death of bacteria.

Mechanism of heat transfer within the food container as it influences F values of heat treatments at various locations in the container during process has been discussed.

A method of process calculation which accounts for the logarithmic order of bacterial death and mechanism of heat transfer within the food container has been proposed.

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THE NUTRITIVE VALUES OF CANNED FOODS
I. HANDLING AND STORAGE PROCEDURES FOR VEGETABLES PRIOR TO CANNING[1]

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Standard practices in the commercial handling of raw products are briefly described, with the explanation that the time involved has been assumed to have little influence on the nutritive value of canned foods. However, instances are given where it is shown that the raw products are held for significant lengths of time before the canning operation.

In 1945, the Departments of Horticulture and Foods and Nutrition initiated an investigation designed to determine changes in the vitamin content of certain vegetables between the times of harvesting and canning. In general, the vegetables were subjected to various storage or holding treatments for different periods of time between harvesting and canning. The Department of Horticulture was responsible for growing, harvesting, handling, and processing the commodities and the Department of Foods and Nutrition assayed both the raw and the canned products for vitamins and rated the canned vegetables for palatability. This paper deals with the handling, storage, and processing procedures employed in the investigation.

PRACTICES IN COMMERCIAL HANDLING OF RAW PRODUCTS

Most vegetables grown for commercial canning are prepared and canned soon after harvesting. The time interval from field to can is usually of such duration that enzymatic and respiratory activities have been assumed to have little influence on the nutritive value of the canned foods. In some instances, however, raw products are held for significant lengths of time before they can be canned. This may be due to one or more of the following:

1. The necessity of having some raw product available to start canning operations early in the day—before that day's harvest from the field is available.
2. The necessity of accumulating sufficient quantities of raw product to justify the start of canning operations.
3. The accumulation of a volume of some vegetables reaching optimum field maturity at one time beyond the capacity of the canning factory.
4. The necessity, in some cases, of transporting vegetables considerable distances from field to factory.
5. The necessity of holding harvested vegetables over weekends or holidays.
6. Interference with normal factory operations by unanticipated breakdowns in the equipment or lack of labor.

Prior to the initiation of the investigation, Mr. H. L. Seaton, Chief Crop Consultant, Continental Can Company, made a survey of practices employed by canners in various regions in an attempt to establish conditions of holding raw products between harvesting and canning. His report is summarized in the following paragraphs:

Spinach: In some areas that grow spinach for both fresh market and processing, it is cut below ground and then packed in bushel baskets or hampers for delivery

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to the canning factory. In other districts, the crop may be cut above ground with machines and then placed in field crates, or even loaded in bulk, to be transported to the factories. Spinach is generally processed the same day it is harvested but reports indicate that it is frequently held overnight and in at least one instance was in transit in refrigerator cars for one to three weeks before processing.

Peas: The time between harvesting and vining operations generally ranges from 1 to 6 hours, with an average of about 3 hours. Time between vining and canning varies from ½ to 12 hours, with an average of approximately 4 hours. Thus the average time from harvest to canning is about 7 hours. Where viner stations are located in the fields, the time between mowing and vining is shortened and the time between vining and canning is longer. If viners are located at or near the factory, the time intervals are reversed. Instances are mentioned where shelled peas are transported in lug boxes for 20 to 40, 60 to 70, and even 120 miles. In some cases, the shelled peas were washed, in one instance iced, before the lugs were loaded into trucks for transportation to the factories.

Green Beans: Handling practices vary widely in different areas of production. In general, the beans are delivered to the factory in cloth bags the day they are picked. They are snipped and canned the same day or the following day. Holding at the factory may be done either before or after snipping. In some areas, the interval between harvest and canning may be as much as one week at storage temperatures approximating those of the atmospheric temperatures. Trucking distances ranging up to 600 miles are mentioned. The shortest intervals between harvest and canning appear to be 4 to 6 hours. On the other hand, most areas report that the holding period may be 1, 2, 3, or even 4 days.

Lima Beans: This crop is usually handled promptly. The average elapsed time from harvest to canning is probably about 6 hours and the range may vary from 4 to 48 hours. When the shelled beans are held overnight or longer, they are usually placed in cold, running water.

Sweet Corn: The usual practice is to pick and can the corn the same day, but often a few loads or bins of corn in the husks are held overnight. The elapsed time from harvest to canning is usually 3 to 6 hours, but may range from 1 to 72 hours. In most areas, holding corn in the husk in wagons, spread on the ground, or in sheds for 25 hours is considered the limit of even poor handling.

Carrots: The methods of handling vary considerably. A more or less typical handling procedure is to haul the freshly harvested carrots to the canning factory yard where they are held in piles until canned. As freezing weather approaches, the piles may be covered with straw. Thus, carrots may be canned immediately after harvest, held for six to nine weeks in outdoor piles, or for several months in cold storage.

FACILITIES FOR GROWING, HANDLING, AND PROCESSING VEGETABLES

The vegetables included in this investigation were grown on the Michigan State College farms in fields of commercial size. They were harvested by the regular canning crops crews at the times the several crops were harvested for regular canning operations. Processing was done in a factory operated by the College for canning vegetables and fruits in No. 10 cans for use in the several dormitories and cafeterias. The experimental lots were run through the regular processing lines, usually by the same personnel employed for commercial canning operations. In cases where the experimental lots were to be canned at other than regular working hours for the factory employees, the authors and one or two assistants prepared and processed the vegetables.

HANDLING, STORAGE, AND CANNING OF EXPERIMENTAL LOTS

Sweet Corn: Two varieties of sweet corn, Golden Cross Bantam and Seneca Golden, were grown in 1945 in a 28-acre field that had been in tomatoes and peas in 1943 and 1944, respectively. There were two planting dates for the former variety. Four rows of corn were harvested simultaneously. The pickers tossed the ears into a wide, flat wagon body where they were spread evenly so that any vertical section of the load might contain corn representative of several rows approximately 100 rods long. The field sample (No. 1, Table 1) for the August 20 harvest was obtained by picking ears from plants in one row at regular intervals throughout the length of the field. Subsequent field samples (Nos. 1) were obtained from a vertical section of the completed load of ears immediately after loading.

The load of some 3,000 pounds was then hauled to the Morrall husker where a vertical section of one-fourth of the load was husked immediately and the husked ears transported about one-half mile to the canning factory. The balance of the load was held in the shade in an open shed for subsequent husking times. For each of these husking times, vertical sections containing representative ears from the entire length of the field were husked and subsequently canned.

Immediately upon delivery of the husked ears to the canning factory, they were run over a sorting and trimming belt, and then through a rotary washer to a Morrall cutter. Each laboratory sample consisted of a No. 10 canful of whole-kernels collected throughout the run as the corn came from the cutter. The cut corn was then conveyed to a rotary screen washer, then flumed to the sorting belt, filled into No. 10 C-Enamel cans at standard fill-in weights, with the usual salt-sugar brine, exhausted for 9 minutes at 160 to 170° F. closed, and cooked for 80 minutes at 240° F. Cooking was usually delayed until enough closed cans were accumulated from regular factory operations to fill three retort crates. Canned corn, as well as the canned lots for other commodities, were stored in the canning factory until time for making the laboratory assays.

TABLE 1

Time schedules and temperatures for sweet corn.

Length of holding period for unhusked ears	Temp. center of load at time husked (° F.)	Elapsed time from harvest to—		
		Husking (hrs.)	Cutting (hrs.)	Cooking (hrs.)
Golden Cross Bantam harvested August 22, 8:55 A.M.				
1. Field sample	63	.....	.....	.....
2. Prompt handling	63	0.7	1.2	2.2
3. Short-time holding	63	4.3	4.6	5.6
4. Moderate holding time	65	7.0	7.6	8.2
5. Long-time holding	60	23.6	24.1	25.0
Seneca Golden harvested August 28, 8:50 A.M.				
1. Field sample	70	.....	.....	.....
2. Prompt handling	70	0.8	1.4	2.3
3. Short-time holding	71	4.3	4.6	5.9
4. Moderate holding time	75	7.3	7.7	8.7
5. Long-time holding	74	23.6	24.1	25.5
Golden Cross Bantam harvested September 4, 9:45 A.M.				
1. Field sample	67	.....	.....	.....
2. Prompt handling	67	0.7	1.2	2.0
3. Short-time holding	68	3.4	3.8	4.9
4. Moderate holding time	71	6.3	6.7	7.4
5. Long-time holding	79	22.4	23.2	23.8

All times given in Table 1, and subsequent tables, are averages. Forty to 50 minutes were usually required to load a wagon during the harvesting operation and about 10 minutes were required to husk and about the same length of time to cut each lot.

The corn harvested August 22 and August 28 was at proper stages of maturity, but that harvested September 4 should have remained in the field another two days for whole kernel packing.

Peas: Three varieties of peas, Thomas Laxton, Pride, and Shasta, were grown in 1946 in a field that had grown peas, tomatoes, and sweet corn in the three preceding years. The field was free from mustard, but there was a rather heavy infestation of lamb's quarter in the areas where Thomas Laxton and Pride were grown. The Shasta peas were harvested from a weed-free area. The approximate yields per acre in terms of pounds of vined peas were: Thomas Laxton, 1,900; Pride, 2,600; and Shasta, 2,700.

The Thomas Laxton peas were harvested at a satisfactory stage of maturity, though it might have been advantageous to have delayed harvest one day. Maximum temperatures for several days prior to the harvest of the Pride variety were in the high 80's and the soil was becoming quite dry. These peas should have been harvested one, or possibly, two days earlier. The Shasta peas were harvested at an ideal stage of maturity from the standpoints of quality and yield. Weather and soil conditions prior to harvest were the same as for Pride. The field sample was collected by pulling individual plants from specific space intervals across the portions of the fields that were mowed subsequently to provide peas for the other lots. All the pods were removed from these plants, taken to the laboratory immediately and shelled by hand.

The peas were cut with a mower equipped with vine lifters and were windrowed behind the cutting bar. Some of the vines, particularly the Thomas Laxton, were loaded onto flat wagon racks by means of a hay loader, but this method proved impractical for the other varieties and they were hand-loaded. The vining station was located about one mile from the pea field and about one-half mile from the canning factory. The pea cleaner was located on the receiving platform of the canning factory. As each lug box was filled with cleaned peas from the experimental lots, its contents were distributed uniformly among the 13 to 16 lug boxes that were to contain the peas for the various holding treatments. Thus, lugs (approximately 30 pounds net) in each experimental treatment contained similar proportions of peas from different portions of the field and from the several bins of the viners and were essentially alike.

The lengths of time required to perform the various operations for the peas that were used for the experimental treatments were as follows: Mowing, 35 to 50 minutes; loading, 20 to 50 minutes; vining, 25 to 85 minutes; and cleaning, 10 to 40 minutes. The rather great variations in times required to perform some of the operations were due to minor adjustments and repairs required for the equipment.

Dates of harvest and the mean time at which each operation was performed for each variety follow: Thomas Laxton, mowed June 27, 1946, 7.40 A.M., vines loaded 7:55 A.M., vined or shelled 9:10 A.M., cleaned, 10:20 A.M.; Pride, mowed July 1, 7:50 A.M., loaded 8:00 A.M., vined 8:30 A.M., cleaned 10:50 A.M. (power failure delayed cleaning operations except for lot No. 2); Shasta, mowed July 2, 7:45 A.M., loaded 8:10 A.M., vined 8:50 A.M., cleaned 9:20 A.M.

After the peas were cleaned and held under the various storage treatments, they passed through a pea washer, were elevated to the blancher over a goose-neck conveyor, were blanched in water for 2¼ minutes at 194° F., cooled, sorted, filled

into C-enamel cans with a salt-sugar brine, exhausted for 8½ minutes at 171 to 176° F,. closed, and then cooked for 55 minutes at 240° F.

Table No. 2 lists the various holding treatments designed for shelled and cleaned peas, the elapsed time from both mowing and cleaning to the taking of the laboratory samples of fresh peas and the start of processing operations, and the temperatures of the peas in the centers of lugs just before preparation for processing.

Lots designated as "in out-door shade" or "in shade" were held in lugs on the covered receiving platform of the canning factory. "Washing" consisted of running the peas through the canning line pea washer and back into lugs. The treatment was designed to remove "viner juice" prior to storage. The peas in "running tap water" were in mesh bags suspended in a tank to which tap water at 52° F. was fed continuously. Peas held "at 33° F." were in a cold storage room where the temperature usually ranged from 32 to 34° F. Some lots of peas were mixed with a small amount of snow ice prior to storage at 33° F. to determine what effect rather rapid reduction in temperature might have on vitamin content. Peas for Lot No. 7 for the Thomas Laxtons were allowed to lie in the mower swath from 11:45 A.M. to about 3:00 P.M., when the air had a temperature of approximately 85° F., and a relative humidity of approximately 50 per cent, and were then handled promptly. In the case of the Shasta variety, Lot No. 7 was supposed to have been mowed about 4:30 P.M., July 2, and to have been loaded about 7:20 A.M., July 3, for prompt subsequent handling. Actually, the workmen loaded two swaths of these peas and one swath of freshly-mowed peas simultaneously, so that this lot must be assumed to be about two-thirds delayed loaded and one-third promptly loaded vines. The minimum night temperature was approximately 52° F.

Table 2 shows that the temperatures of the peas held in the shade increased with the length of the holding period. However, air temperatures increased more rapidly than did pea temperatures, so that there was no evidence that the rise in pea temperature was due to biological activity. Washing lowered the initial temperatures of the peas 6 to 8° F. and after 7 to 8 hours of holding, these peas were 4 to 7° F. cooler than comparable unwashed peas. The reduction in temperature of lugs of peas held in 33° F. air during the first 21 to 23 hour period ranged from 20 to 25° F. Washing prior to refrigerated storage resulted in somewhat more rapid lowering of temperature during these holding periods. The use of snow ice increased the rate of cooling approximately 50 per cent during the first day's holding under refrigeration.

Green Beans: The first harvest from a field of Landreth's Stringless Greenpod was made July 31, 1946, and the second harvest, August 5. The first picking for a variety listed as B 1151 was made August 23. Practically no rainfall occurred during the latter half of June and the time the second picking was made, and only 0.8 inch of precipitation occurred in August prior to the harvest of B 1151. Consequently, the available soil moisture was very low during a major portion of the growing season.

The field sample was collected by picking mature pods from plants at specific intervals throughout the length of three rows. They were taken to the laboratory immediately, where they were snipped and cut by hand.

The beans were picked by hand during the early portions of the days and delivered in bushel baskets to one end of the field where the contents of each basket were evenly distributed among other bushel baskets representing each experimental lot. Each lot of beans, about 35 pounds, was then transferred to mesh bags and these were transported to the canning factory or refrigerated storage, according to the holding treatment to which each lot was to be subjected.

TABLE 2

Holding treatments, actual elapsed times, and temperatures for peas.

Variety	Thomas Laxton			Pride			Shasta		
Holding treatment	No. hours from		Temp. of peas	No. hours from		Temp. of peas	No. hours from		Temp. of peas
	Mowing to processing	Cleaning to processing		Mowing to processing	Cleaning to processing		Mowing to processing	Cleaning to processing	
1. Field sample	....	....	70	....	....	66	....	....	64
2. Prompt handling	3.4	0.7	70	2.1	0.5	68	2.3	0.7	61
3. In outdoor shade	7.0	4.3	79	5.4	2.4	71	5.5	3.9	65
4. In outdoor shade	....	....	....	10.9	7.9	74	9.0	7.4	68
5. Washed, then in shade	7.0	4.3	67	5.4	2.4	62	5.5	3.9	60
6. Washed, then in shade	....	....	....	10.9	7.9	67	9.0	7.4	64
7. Loading delayed after mowing, then prompt handling	4.3	0.1	85	....	....	....	17.3	0.7	59
8. In running tap water	10.8	8.1	57	10.9	7.9	57	9.0	7.4	58
9. At 33° F.	11.0	8.3	61	10.9	7.9	52	9.0	7.4	50
10. At 33° F.	24.0	21.3	45	26.4	23.4	46	25.3	23.7	41
11. At 33° F.	48.0	45.3	40	44.9	41.9	37	....	....	....
12. Washed, then at 33° F.	11.0	8.3	53	10.9	7.9	48	9.0	7.4	47
13. Washed,then at 33° F.	24.0	21.3	40	26.4	23.4	40	25.3	23.7	39
14. Washed, then at 33° F.	48.0	45.3	37	44.9	41.9	37	....	....	....
15. In snow ice and 33° F. air	24.0	21.3	33	26.4	23.4	35	25.3	23.7	33
16. In snow ice and 33° F. air	48.0	45.3	35	44.9	41.9	37	....	....	....

The times required in the field to harvest and prepare the several lots of beans for their respective treatments were approximately 105 minutes in the case of the Landreth's Stringless Greenpod, and about 150 minutes in the case of B 1151. The elapsed times from the mean harvest periods to the times when the various lots were initially subjected to their various holding treatments were: first picking, 110 minutes; second picking, 100 minutes; and third picking, 90 minutes.

An attempt was made to determine moisture losses for the various lots during the holding periods. Such losses are listed in Table 3. While there are a number of unexplained inconsistencies, the general trend was in the direction of increased weight loss, due mostly to moisture loss, with holding or storage time. These trends were especially striking in the case of the B 1151 variety which lost 6 to 9 per cent weight during holding periods of 72 hours or more in both outdoor shade and cold storage. There was no indication that green beans tend to "heat up" during holding under the conditions of these tests. In forced air circulation cold storage, green beans in mesh bags placed in small piles cool rapidly, the rate being 28° F. in approximately 9 hours. There was no indication that supplementary snow ice is essential for green beans stored soon after harvest at 33° F.

After the completion of the holding periods, the beans were sorted as they passed over a belt leading to the snipper and thence to the cutter. A goose-neck conveyor delivered the cut beans to a hot-water blancher where they were subjected to 190 to 195° F. for 3.2 minutes. They were then cooled with a water spray and run over a sorting belt to the can filler. The beans were packed in No. 10 plain tins with water and salt and then exhausted at 175° F. for 8¾ minutes. When enough cans accumulated to fill 3 retort crates, the beans were cooked for 35 minutes at 240° F.

Lima Beans: One portion of a field of Thorogreen lima beans was harvested September 16, 1946, and the balance, September 19. The vines were cut with a dry-bean harvesting machine, loaded on flat wagon racks by means of a hay-loader, and shelled with a pea viner equipped with lima bean screens. The low summer precipitation resulted in almost continuous blooming and it was necessary to harvest when the beans resulting from the early setting were mature. Consequently, yields were low.

The methods employed to obtain uniform lots of cleaned lima beans for the various treatments were essentially the same as those described for peas. Each lot consisted of a lug containing approximately 30 pounds of beans. Experimental treatments were similar to those previously described for peas except that two lots were dipped in a 10 per cent solution of calcium propionate prior to the holding treatments to determine if such treatment would reduce microbiological activity on the surfaces of the beans sufficiently to prevent "heating."

The limas were processed in the pea line of the canning factory. They were water-blanched at 194° F. for 3½ minutes, filled into No. 10 plain cans with water and salt, exhausted for 8½ minutes to a temperature of 180° F., and cooked for 55 minutes at 240° F.

Since there are only a few short-time holding treatments in these tests, the actual lengths of the various holding treatments are not given in Table 4, but they may be assumed to be 1.5 hours shorter than the elapsed time shown for harvest to processing for all lots.

The most interesting fact in Table 4 was the tendency for the limas held on the receiving platform, in the shade, to increase substantially in temperature. Lots 3, 4, and 5 of the first harvest had middle-lug temperatures of 73, 81, and 98° F. at the ends of their respective holding periods, while the air temperatures at the

TABLE 3

Holding treatments, elapsed times from harvest to processing, temperatures prior to processing, and weight losses for green beans.

Variety	Landreth's Stringless Greenpod						B-1151		
Holding treatment	First picking			Second picking					
	Hours-harvest to processing	Temp. of beans	Wt. loss (%)	Hours-harvest to processing	Temp. of beans	Wt. loss (%)	Hours-harvest to processing	Temp. of beans	Wt. loss (%)
1. Field sample	....	69	....	....	69	....	....	65	....
2. Prompt handling	2.1	71	....	1.9	69	....	1.6	65	....
3. In outdoor shade	5.1	71	....	5.4	70	2.8	6.0	65	2.2
4. In outdoor shade	11.0	70	2.9	11	67	3.1	....	....	....
5. In outdoor shade	24	62	3.3	24	66	5.3	23	55	3.9
6. In outdoor shade	48	62	2.5	48	64	4.4	....	....	....
7. In outdoor shade	....	....	....	....	....	....	72	59	7.5
8. At 33° F.	11	41	2.9	11	41	3.7	....	....	....
9. At 33° F.	24	37	6.0	24	35	2.7	23	37	1.7
10. At 33° F.	48	35	6.0	48	34	4.2	....	....	....
11. At 33° F.	72	34	2.7		....	....	72	32	3.2
12. At 33° F.	....	....	....	120	34	5.3	....	....	....
13. At 33° F.	....	....	....	....	....	....	143	33	6.0
14. At 33° F.	....	....	....	....	....	....	263	34	9.1
15. In snow ice and 33° F.	48	35	....	....	....	....	....	....	....
16. In snow ice and 33° F.	72	32	....	72	34	....	....	....	....
17. In snow ice and 33° F.	....	....	....	120	34	....	....	....	....

TABLE 4

Holding treatments, elapsed times from harvest to processing, and temperatures of Thorogreen lima beans at the termination of holding treatments.

Holding treatment	First harvest		Second harvest	
	Elapsed hours harvest to processing	Temp. of beans	Elapsed hours harvest to processing	Temp. of beans
1. Field sample	----	67	----	70
2. Prompt handling	1.9	67	1.5	64
3. In outdoor shade	5.2	73	5.2	70
4. In outdoor shade	9.2	81	8.2	75
5. In outdoor shade	24	98	24	97
6. In running tap water	9.2	57	8.2	56
7. In running tap water	24	55	24	67
8. Washed, then in shade	9.2	66	8.2	67
9. Washed, then in shade	24	74	24	76
10. Calcium propionate dip, then shade	24	76	24	75
11. At 33° F.	24	57	24	47
12. At 33° F.	48	----		
13. At 33° F.	120	38*		
14. Washed, then at 33° F.	120	36*		
15. Calcium propionate dip, then 33° F.	120	37*		
16. Snow ice and 33° F. air	24	35		
17. Snow ice and 33° F. air	120	36*		

*Storage room temperature was 36° F. at time of removal of limas.

respective times were 81, 73, and 62° F. These lots for the second harvest had temperatures of 70, 75, and 97° F., while air temperatures at the same times were 83, 77, and 59° F., respectively. Thus, after 24 hours of holding in the shade, the bean temperatures were 36 and 38° F. higher than the surrounding air temperatures. The limas that were washed prior to the holding treatments developed substantial temperature increases during the 24-hour period in shade, but washing evidently removed a sufficient amount of "viner juice" to lower the biological activity on the surfaces of the beans. A cilcium propionate dip was no more successful than washing in water in preventing the development of high temperatures in the beans held at shade temperatures. Suspending the shelled limas in running tap water held the temperatures of the limas at low levels. Lot No. 7 of the second harvest had a temperature of 67° F. at the end of 24 hours but it is likely that the rate of flow of the water was too low during the night.

The lots placed in cold storage cooled slowly. Lot No. 14, which was washed prior to storage, had a fresher and better general appearance on removal from storage than other lots held for 5 days.

These handling treatments show that it is essential that lima beans be processed soon after the vines are cut. If it becomes necessary to hold the beans overnight, they should be placed in a tank having a liberal and continuous supply of cold water or they should be hydrocooled and placed in cold storage.

*Carrots:** Approximately one ton of Red Cored Chantenay, muck grown carrots were harvested October 21, 1946. About 50 per cent of the carrots had growth cracks and there was some evidence of aster yellows at the time of harvest. The carrots were 2½ to 3 inches in diameter and 4 to 6 inches long.

After Lot No. 1 was processed, the balance of the carrots was divided into two lots for storage. One portion, in slatted field crates, was placed in cold storage

*The authors are indebted to Dr. S. H. Wittwer for handling the carrots prior to processing.

and the other was placed in an outdoor pile and covered with sufficient straw to prevent freezing.

The cold storage holding was expected to provide an average temperature of 31 to 32° F. and a relative humidity approximately 90 per cent. Because of the crowded conditions and overloading of the storage rooms, temperatures during the first 10-day period ranged from 33 to 48° F., with an average of about 43° F. The temperatures for the balance of the storage period ranged from 32 to 34° F., with an average of 33.3° F. Relative humidity during the first 10 days ranged from 85 to 95 per cent and subsequently from 78 to 92 per cent, with an average of 85.3 per cent. The combination of the several factors, such as growth cracks and aster yellows, high temperatures during the early storage period, and a fluctuating and rather low average relative humidity resulted in rather poor storage conditions. Consequently, the weight losses during cold storage were very high.

The out-door storage was rather typical of such holding under similar conditions of weather. The fall of 1946 was characterized by more or less continuous high temperatures. The mean monthly temperatures at East Lansing were: October, 55.7° F.; November, 41.6° F.; and December, 30.2° F. Thus, the October and November means were 5.4 and 4.1° F., respectively, above normal. The temperatures in the pile of carrots were 62° F. on October 29, 51° F. on November 5, and ranged from 44° F. on November 12 to 32° F. in early January, with an average of approximately 37° F. Weight losses for these carrots were not obtained, but they evidently were low. Weight losses due to loss of moisture are usually slight in root crops held in outdoor covered piles, since the underlying soil supplies some moisture to the vegetable, and the straw covering prevents direct exposure to the outdoor air currents.

Processing consisted of sorting, cleaning in a rotating squirrel cage washer under strong jets of water, blanching in a retort for 15 minutes at 5 pounds pressure, peeling in a friction peeler, washing under jets of water, sorting and trimming, dicing and filling into plain No. 10 cans with hot water and salt, exhausting 8½ minutes to 171-174° F., closing and cooking for 45 minutes at 240° F.

TABLE 5

Holding treatments, elapsed times, and temperatures of carrots prior to processing.

Holding treatment	Elapsed time	Temp. of carrots	Weight loss during storage (%)
1. Prompt handling	0	....	....
2. Outdoor straw-covered pile	One week	62	....
3. Outdoor straw-covered pile	One month	40	....
4. Outdoor straw-covered pile	Three months	38	....
5. Cold storage, carrots in crates	One week	48	3.1
6. Cold storage, carrots in crates	One month	33	9.4
7. Cold storage, carrots in crates	Three months	33	28.0

Spinach: The first harvest of spinach came from a fall-planted upland field near Grand Rapids. The raw product was of good quality but there was evidence of aphis injury. It was supposed to have been harvested during the early forenoon of May 21, 1947, but the grower, anticipating rain during the previous night, harvested it about 8:00 P.M. May 20, and packed it tightly in bushel baskets. The spinach and baskets were wet on delivery, showing evidence of having remained in the field during rain. This spinach was delivered to the canning factory about 10:40 A.M. and the various holding treatments initiated about 11:30 A.M., some 15 hours after harvest. Trimming consisted of breaking off butt portions of about

1½ to 2 inches, leaving most of leaf petioles and the tips of the central stalks. Each holding treatment consisted of 3 baskets except Lot No. 6. In the case of the latter, 4 baskets of spinach were piled loosely, in bulk, in the shade on the floor of the receiving platform at the canning factory.

The second harvest was muck-grown spinach from spring planting, harvested June 20, 1947. It had been cut above ground and it had no large stalks such as characterized that of the first harvest. The leaves were much thinner than the upland-grown crop, but the quality was very good. Most of the small stalks were reddish at the bases and these portions were removed in trimming. This spinach was harvested and packed in bushel baskets between 8:00 and 8:15 A.M. and

TABLE 6

Holding treatments, elapsed times, and temperatures of spinach prior to processing.

Holding treatment	First harvest—upland grown			Second harvest—muck grown		
	Elapsed time from—		Temp. of spinach (°F.)	Elapsed time from—		Temp. of spinach (°F.)
	Harvest to processing (hrs.)	Start of treatment to processing (hrs.)		Harvest to processing (hrs.)	Start of treatment to processing (hrs.)	
1. Direct from field	....	....	....	....	....	58
2. Prompt handling	17	2	62	2	0	58
3. In baskets in shade	21	6	62	7	5	64
4. Baskets in shade	37	22	57	24	22	70
5. Baskets in shade	....	....	....	72	70	77
6. Bulk pile in shade	37	22	51	25	23	67
7. At 33° F.	37	22	47	25	23	44
8. At 33° F.	61	46	50	....	....	....
9. At 33° F.	....	....	....	73	71	35
10. At 33° F.	133	118	36	....	....	....

promptly trucked some 16 miles where the various holding treatments were started less than two hours after harvest. Each lot consisted of 3 bushels except Lot No. 6, which again consisted of 5 bushels piled loosely in the shade, and Lot No. 5 which was held in baskets in the shade 3 days. All lots showed considerable wilting of leaves exposed to the air after severeal hours. Lot No. 5, held for 3 days in the shade developed a final temperature of 77° F. and showed an excessive amount of decay at the end of the holding period, while Lot No. 9, held in cold storage for 3 days, was in good condition except for wilting of leaves in the top of the baskets.

The trimmed spinach was washed in the equipment previously described for washing ears of corn and carrots. It was then blanched for 7 minutes by first suspending the spinach in a retort crate in water at 170° F., then in water at 212° F. for 4 minutes, and then suspending the crate in cold water until cool enough to handle. The spinach was then filled into No. 10 cans, salt and water added, exhausted for 8½ minutes to a temperature of 172° F., closed, and then cooked for 100 minutes at 240° F.

THE IMPORTANCE OF COLLOID CHEMISTRY IN FOOD TECHNOLOGY*

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The importance of colloid chemistry to the Food Technologist is discussed in detail, with many examples presented to show how this science could assist in solving every day problems in food production.

GENTLEMEN:

I consider it a great honor to be asked to address you today and lead a discussion on the topic, "The Importance of Colloid Chemistry in Food Technology."

As you know, I am a member of the staff of the Massachusetts Institute of Technology, but I would like to add to this simple statement that I am particularly proud of being a member of the faculty for one reason, and that is that to the best of my knowledge M. I. T. is today the only university or school of technology in the United States which in its curriculum has not one, but four classes specifically in colloid chemistry and its industrial applications, and sees that the students take those courses.

I consider it my primary objective to define to you tonight the modern concept of colloid chemistry and why it is not only advisable, but imperative that your organization takes more cognizance of this branch of science than it has so far.

I am quite convinced that there is not one person in this group who has never been to a movie, and when the light was turned off and the projector started throwing "Mickey Mouse," or whatever it was, onto the screen, you have seen the path of light from the projector lens to the screen and when the lights have been turned on, as they appear in this room now, you could not see anything and you have thought it was beautiful, clear air. The reason why you see that path of light is because minute dust particles are floating around in that air and the light coming from the projector hits those particles, and what you see is not the particles but the reflection. That was discovered by Michael Faraday in 1861, but it took until 1905 for somebody to draw a logical conclusion, namely, why isn't it possible to look at that beam of light through a microscope; and it was the discovery of the ultra microscope, as it is called today, which started the science of colloid chemistry.

Until recently the most generally accepted definition of colloids, and, unfortunately, the one still too frequently heard today, is that colloid chemistry is just a side branch of physicochemistry pertaining to particles floating around in a liquid or gas but so small that they cannot be made visible in a standard type of microscope. This is not the case. The best definition of colloid chemistry I can offer is based on the title of a book written thirty years ago by one of Germany's leading scientists, and I must admit, hard as it might sound, that the Germans were the pioneers in that field of science. The man I am referring to is the late Prof. Wo. Ostwald, who while in the trenches during the first World War, when there was not too much fighting going on, wrote his first text book on colloids, and he entitled that book—and I am going to translate this—"The World of Neglected Dimensions"; and to this I would like to add my own version.

Ladies and Gentlemen, it is high time that we stop neglecting these dimensions and take more cognizance of why and how they affect our daily life and also how they can be put to use to solve many problems with which your industry is faced

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today. Now, that is a strong statement and you are therefore absolutely entitled to ask, "Can you back that up?" So I am going to try to do it, and to do that I must be a bit more specific for a few minutes.

Any matter, organic or inorganic in composition, a little corpuscular particle, an extremely thin thread, or a film or coating of extreme thinness is a colloid if its exposed surface is preponderant in comparison to its volume. Let us use quite simple mathematics for a moment. A cube of 1 cm. edge length has a volume of 1 cubic centimeter, a surface of 6 square centimeters, 12 edges, and 8 corners. Now let us subdivide this cube into cubes with an edge length just below the visible range of a standard microscope, 0.0005 mm., or one-half of a micron. We have produced 8 million million cubes. Their combined volume is still one cubic centimeter. Their total surface, however, has been increased to the fabulous figure of 12 square meters. They will now expose 64 million million corners, and 96 thousand million million edges. In the center of a crystal, for example, the ions composing it are surrounded by others resulting in their chemical or, if I may be quite fancy, electronic saturation or balance. But the same ion located in its surface is not so fortunate—it lacks its partners on one side, those at an edge on two, and the corner ions even on three, to balance their desire for saturation. Does this, gentlemen, explain to you why matter in the colloidal range of dimensions is so exceptionally reactive, and why its properties cannot be explained or harnessed by the rigid laws of physico-chemistry?

Now there is one more thing I want to mention before giving you several direct examples of the importance a more sincere appreciation of colloid chemistry would deserve in the science and industry you are representing. The stability of colloids depends basically on their surface composition. If it is built up of ions which have no affinity for the medium surrounding them, then the colloid will depend for its stability on the net electric charge of its surface and the concentration of ions of opposite sign in its proximity. As soon as its surface charge is neutralized the colloid loses its stability and coagulates. Colloids composed of ions or molecules having affinity for the medium in which they are placed do not need these counter-ions. They swell and eventually go into the state of a gel, and if their concentration is reduced or their temperature raised, they go into solution. If, however, one adds to such a sol a medium for which the colloid has less affinity, the picture changes and we revert to our starting point; the colloid is desolvated. To give you an example of these two phenomena there is no need to set up an elaborate lecture demonstration. Have you ever thought why you can stop bleeding after you have cut yourself with a razor blade and used a wetted alum stone? Your blood corpuscles are colloidal particles carrying a net negative charge. The aluminum ions of the alum are powerful positive ions. They neutralize the charge of your blood particles and clotting results. Your brain is a colloidal gel with affinity for water. Sleep is needed to replenish the water lost during the day's work. But if you add to your system a liquid which has less affinity for your brain colloid than water, it will be very rapidly desolvated. Alcohol is such a liquid and depending on the concentration of the intake, you will be either a bit cheered up or just plain drunk.

Now, I think it is time to give you some more specific examples from your field of activity. You deal frequently with emulsions. An emulsion is a system containing two liquid phases, one of which is dispersed as globules in the other. That liquid which is broken up into globules is termed the dispersed phase; the surrounding medium is known as the continuous phase or dispersing medium. The two liquids must be immiscible. If they are shaken together or otherwise agitated, they will temporarily produce an emulsion, but as soon as agitation ceases, the drops coalesce and separation into two layers occurs. The emulsion has broken. To produce a truly stable emulsion we must again rely on the teachings of colloid chemistry.

What we need is an emulsifying agent. Now what is this and what does it do? If we want, for example, an oil in water emulsion, we must add a compound which is more readily wetted by water than by oil. Sodium oleate is such an adsorbable substance. However, if we use calcium oleate we will obtain after agitation a water in oil emulsion, because the calcium is less wetted by the water than the oleate radical by the oil. In both cases the oil or water droplets are coated with a layer of soap and the emulsified phase now acts as a colloid of the reactivity of the emulsifying agent. Your industry is full of such oil in water emulsions. Let us take mayonnaise as one example because its production gives you a good idea of the importance several factors play in colloid chemistry which have no significance at all in normal chemistry.

And before going on to quote from a British colleague of mine, I would just like to tell you one thing and then ask a question. If you put silver nitrate into solution and potassium bromide into solution—I assume that most of you are chemists—and if you mix those two together you will form silver bromide which is non-soluble. That is all inorganic chemistry can teach you, and teaches you, but do you realize that it makes considerable difference what concentrations of those two reacting solutions you use? If you use one system where you have more silver nitrate than potassium bromide, do you realize you will form a silver bromide precipitate which, when dispersed in water, will move from the negative to the positive pole? If you start with a higher concentration of potassium bromide than of silver nitrate, you will wind up with a colloidal dispersion of silver bromide, but this time it goes to the negative pole. That is colloid chemistry. It is the chemistry of surface phenomena and nothing else.

I shall now quote in part from a publication of one of my British colleagues, J. W. Corran, Chief Chemist of J. & J. Colman, Ltd.:

"It is evident to those who have a knowledge of emulsion chemistry that the Food Industry provides a fruitful field for the application of such knowledge. . . . A complete understanding of the digestion of our food, particularly of fats, is dependent, amongst other things, on a knowledge of emulsions and emulsification. In fact, in a short paper it is quite impossible to do justice to a general survey of such a large field of application of emulsions as is presented by the Food Industry.

"Given a certain formula for mayonnaise, it might well be thought that it would be an easy matter to obtain a product of the maximum stability. This, however, is not the case.

"The following will indicate a typical commercial formula for a mayonnaise omitting those flavouring ingredients which do not exert an effect on the persistence of the emulsion:

Oil	75.0%
Salt	1.5
Egg yolk	8.0
Mustard	1.0
Water	3.5
Vinegar (6% acetic acid)	11.0

It will be observed that the ingredients mentioned are oil and water (the dispersed and continuous phases respectively), egg yolk and mustard (emulsifying agents) and vinegar, which has a relation to the question of emulsification.

"It has already been stated that egg yolk is the most efficient edible emulsifying agent in the production of oil-in-water (creamy) emulsions. Egg yolk, however, is not a simple substance, but consists of a mixture of protein, fat, water and mineral salts, etc., of the order indicated in the following analysis:

Protein	16.0%
Fat	23.0
Lecithin	11.0
Cholesterol	1.5
Salts	3.0
Water	45.5

"Although the protein content of the yolk has undoubtedly an emulsifying effect, the most important factor in this connection is to be found in the phosphatide content of the fat. Egg fat contains about 33 per cent. phosphatide, which largely consists of lecithin. In addition, it contains the substance cholesterol in amounts of the order of 5 per cent."

The colloid chemist knows that lecithin is a very powerful agent in promoting oil in water type of emulsions, whereas cholesterol promotes the water in oil type. If you use the yolk of stored or frozen eggs the lecithin has undergone a chemical change of a hydrolytic nature accompanied by loss of its emulsifying property. Cholesterol being stable under the conditions gets the upper hand and a noticeably less stable mayonnaise results.

It is also against any rule of colloid chemistry to prepare a nucleus of all the oil emulsified in a fraction of the water prior to adding the remainder of the aqueous phase. This must have an adverse effect on the stability of the final product. Homogenization must also be scrutinized from a colloidal viewpoint. By this technique we increase the interface and if we do not add proportionally more emulsifier an unstable emulsion results. If you have no soft water to make your food emulsions with, you will be out of luck when you are attempting to get an oil in water type. In the case of mayonnaise you might avoid this danger by adding a bit more mustard. It acts like a sodium soap and therefore counteracts the effect the calcium of hard water exerts on emulsification. All problems of gelation are based on colloidal phenomena and cannot be explained by any teaching of standard chemistry. The formation of gels depends on a great number of factors which must be taken into consideration if one wants to achieve just what one is looking for. Here the colloid chemist is just irreplaceable.

Another problem with which the food industries are confronted was only recently brought to my attention in an excellent lecture by Dr. Cecil G. Dunn, on "Chemical Detergents." The use of detergents for the cleaning of soiled glassware or metal containers is based exclusively on colloidal phenomena. However, what struck me most was a statement made by a member of the audience to the effect that he could not understand why a wetting agent like hexametaphosphate cleans bottles better than a solution of sodium hydroxide. The colloid chemist has the answer. The phosphate is adsorbed on the surface of the particles which are deposited on the glass or tin. The electric charges of the particles are thereby increased, resulting in the rapid dispersion and removal of the particles by washing.

Another direct application, another field of colloid chemistry in food technology is in the brewing industry. If you took some good German or Czechoslovakian brew and poured it out into your stein from a certain height you would form a pretty fine layer of foam, and do you realize that you could let that beer stand there for half an hour, or an hour, and that layer of foam would remain, it would not collapse. You try it with one of our beers that you take out of your refrigerator at home. You will find that it won't stand up so long. Why? We have to remove the protein since it won't stand the freezing or low temperatures so long, and the protein is responsible for the foam, and the taste, to quite a large extent.

Your industry is also full of waste problems and there is a tremendous chance for the application of colloid chemistry. May I just give you one example. In the manufacture of starch, for example, we used to grind potatoes, or whatever it may have happened to be; the starch in the grinder settled out and the water went to waste. Do you realize that that water contained a fairly high concentration of proteins. A nation that is not so fortunate as we—living in abundance as we do—cannot afford that waste, and I think it is time for us to think about it, too. The Germans solved that problem, also, by colloid chemistry, and what they did was this: They knew that the proteins which have been put into solution by removal of

the starch grains are what we call capillary-active or surface-active proteins. That means they have a tendency to reduce the surface tension and, therefore, they concentrate in the surface. So, if we agitate such a fluid, we concentrate the protein in the surface, and can thus collect it.

And so, ladies and gentlemen, I hope that I did not overstretch my point of view, but I quite frankly believe that the whole field of food technology, in its own interest, must start giving the teachings of colloid chemistry more serious consideration than it has up to now. If you do that, I am convinced that you will find many very interesting things and that your industry will benefit tremendously by the application of colloidal chemistry and its teachings. So let me just say that I think it is really high time to remember that colloid chemistry is nothing but the science of the properties exhibited by matter present in particles of such small dimensions that they have been neglected in the past.

Thank you.

SYMPOSIUM—DISCUSSION

CHAIRMAN R. S. SCULL: Thank you, Dr. Hauser. We all have problems in the colloid field but we don't always recognize them as such. We might make a new approach to our problems or make a resolution to investigate what help we can get from a deeper study of our colloid chemistry.

There are two excellent books that have intrigued me—one by William Clayton, of Scribbans-Kemp, Limited, in London, who approaches our food problems from a colloidal viewpoint, and the other is by Dr. Belle Lowe—an excellent book, an intensive, practical book called "Experimental Cookery." In her preface, Dr. Lowe points out that one of the threefold purposes of her book is to draw on the field of colloid chemistry for an explanation of what goes on.

We, as technical men, are really the custodians of the progress of our great industry. I think that, in World War II, it was demonstrated that a large part of our power lay in our ability to step up our food production and provide foods for ourselves and our Allies, not only in this country but in the other countries in which we operated.

We have a tremendous responsibility in the face of a world deficit of food, and I think we can solve it. Some of the waste, for instance—let's pay more attention to our colloid chemistry in our efforts to reclaim that, instead of sending it down the sewers. On so many acres of land we can produce so many tons of food. We don't really know what our economic wastes are until we go after them with a fine-tooth comb.

We have many industries represented here and the problems are manifold. I am thinking of many of them that I have seen in the past. They are not only the problems which have been suggested this evening by Dr. Hauser as being solvable, but many others as well. One, for instance, is the improvement of the flavor of our foods. The colloidal state has much to do with the flavor of various food preparations, and if we knew just what we were doing in our factory operations we might improve the flavor and make the public acceptance greater. Also, the physical state, or the texture, of the foods that we manufacture, could be greatly improved if we understood and applied more of the findings of the science of colloid chemistry. I have in mind, for instance, the cans of spaghetti and tomato sauce that we open, to find a yellowish separation in the top of the can while the tomato sauce is coagulated below, among the strands of spaghetti. We have cheese sauces which have a water phase along with a solid phase. We have jellies that have syneresis. We have all sorts of problems of the colloidal state, because the food

technologists in charge of operations do not know the colloid factors in regard to flavor.

I think we should discuss these problems tonight, hoping to start a train of thought that will leave a memory of this Conference with us when we go back to our respective companies and interests, so that we will come back next year with our minds filled with problems that we would like to discuss among ourselves. I am sure we will find answers which will not only improve our own knowledge but will also result in improvement of our respective companies. Is there anyone who would like to start a discussion of any of his problems or a discussion with Dr. Hauser on any of the things about which he has told us?

DR. G. T. REICH: Dr. Hauser, I would like to ask you about a problem which the sugar refineries have. A refinery which refines approximately four million pounds of sugar a year has to have from three to five million pounds of bone-char in its plant in order to remove a small amount of colloid. At the same time I found that I could not remove all the colloid with bone-char (which is animal char) but I could remove part of it with a vegetable char or a combination of the two. Sometimes the colloids are iron polyphenols and of red coloration. If you add a little alkali to it the resulting sugar has a grayish tint. If you add, for instance, some organic solvent such as alcohol or iso-propyl alcohol—which cannot be done commercially—you can partly separate them. The question is, how could you do that in a water solution?

DR. HAUSER: If I understood you correctly, you want to know how you can separate the ions?

DR. REICH: No, how you can break up the colloid.

DR. HAUSER: Which is supposedly iron?

DR. REICH: Yes, iron poly-phenols. There is not only one, but there are other colloids, too.

DR. HAUSER: First of all, you would have to ascertain definitely what type of colloid you are dealing with. Secondly, you must ascertain—and this is easily done, assuming this is all in a water dispersion—what charge, if any, those colloidal particles carry. If you know that you can separate them by various methods. You can add an electrolyte, which will cause a flocculation of that colloid, or you might be able to remove or separate them by centrifuge. Since you mentioned the presence of iron it is very probable that the colloid you have is iron hydroxide, which results in a colloidal system that has a tendency to form a gel if allowed to come to rest, like this one I showed here. But that can be regularly disturbed and destroyed by the addition of an appropriate electrolyte which will discharge that colloidal system, whereas your other product would not be affected by that treatment.

CHAIRMAN SCULL: Have you any further questions?

DR. REICH: Yes. In mayonnaise frozen egg yolks are commonly used. Dr. Hauser makes the statement that freezing destroys some of the lecithin, and lecithin being an emulsifying agent, some of the properties of the eggs are thereby destroyed. What is the alternative? Would one be justified in adding some of the lecithin now on the market?

DR. HAUSER: How much mustard have you in your mayonnaise?

DR. REICH: About 1%.

DR. HAUSER: Have you tried 2%?

DR. REICH: Yes.

DR. HAUSER: Did it not help?

DR. REICH: The question is, we realize that that is the case; that some of the lecithin is destroyed. Is there any alternative? Since mayonnaise men are obliged

to use frozen eggs, would one be justified in adding lecithin to replace that which is destroyed?

DR. HAUSER: Yes, but lecithin would have to be obtained from another source which has not been in the freezing condition.

DR. REICH: The lecithin now on the market, I understand, is obtained from soy beans.

DR. HAUSER: That's right.

DR. REICH: And that would help?

DR. HAUSER: Yes, the main thing is that during the freezing the lecithin loses its emulsifying activity.

DR. H. E. GORESLINE: Is that the reason it is required that salt be added to egg yolks before they are frozen—to prevent the gelation of the lecithin? A great deal of the egg yolks that are used by the mayonnaise people are frozen with salt and that prevents the gelation of the lecithin.

DR. HAUSER: It is not a question of gelation of lecithin during freezing. It is a question of decomposition from a colloidal point of view, and I am not quite sure that the addition of a salt alone will do it. It might to some extent but I don't think it will completely. You could, naturally, add another stable emulsifying agent of the proteins.

MR. MONTGOMERY: Those of you who are interested in mayonnaise may recall having read a number of years ago about some experimental work which was done. I don't recall the authors' names, but they separated lecithin from raw egg yolk and attempted to make mayonnaise from that and were unsuccessful. They put forth the theory that lecithin was present in the egg yolk in combination with protein. I wonder if anybody here is familiar with any more recent work done along that line; or if anyone has actually made mayonnaise without egg yolk, using only lecithin?

DR. HAUSER: To my knowledge, some British companies have done that quite recently, successfully, but they still maintain that it is always advisable to add a counteracting agent—mustard is an example—and their investigation is now along the lines of finding a substitute for mustard—of the same efficiency. No results have been published along those lines.

CHAIRMAN SCULL: Dr. Hauser, what agent is in the mustard that contributes to the stability of the emulsion?

DR. HAUSER: That I don't know.

CHAIRMAN SCULL: Is there anyone else in the audience who has any ideas about the lecithin and the proteins as stabilizing agents in mayonnaise emulsion?

MR. J. J. SAMPEY: I think a positive problem in the freezing of egg yolk could be solved by the addition of 10% or 15% of sugar. We find in the dairy business that if we freeze whipping cream with that amount of sugar ice cream made from it is greatly enhanced.

I would also like to ask your opinion on another subject: the use of some of the newer emulsifying agents, Solvato and Polatol, non-protein aids and protein aids. I have tried them in ice cream mixes very successfully. I wonder if you have any opinion as to the best way. They have very strong emulsifying powers in other solutions. If you have any remarks on those questions I would like to hear them.

DR. HAUSER: I have had no experience along those lines; but have you ever tried to determine the changes in the surface and interfacial tension on the addition of those different ingredients?

MR. SAMPEY: No, just patent results only.

DR. HAUSER: I think that you would find it was very worth while to work that out, and I think you would then get a final answer right away. To me, from my experience, it is unquestionable that this is primarily an interfacial tension phenomenon. In the lecithin case it is quite different. There you found that the difference in the interfacial tension is remarkable between non-protein and protein.

MR. HARMON: I would like to ask one question in connection with mustard. Dr. Hauser, the essential oil is the important thing. Is that the function of the flower portion or of the seed?

DR. HAUSER: The flower itself, seemingly.

MR. HARMON: It is the flower itself rather than the mustard seed?

DR. HAUSER: Yes.

MR. LAMBDEN: I think that possibly I might be able to give some additional light on this matter of lecithin protein. When you freeze egg yolk there is an increase in some of the solids, the electrolytes, which may cause a denaturation or coagulation of protein. It is known that a high concentration of salts, etc., will do that to protein. Now one reason, for example, why sugar is added to protein is because the addition of certain sugars and salts does prevent this denaturation. For example, I think egg yolk will coagulate at about 70° C. If you add sugar to it, or some other electrolyte, you boost the coagulation of the egg yolk. If you add sugar to egg yolk you do prevent this coagulation and denaturation of freezing. The gentleman brings up the point that it may well be lecithin protein that is found in egg yolk. If the protein is denatured, it may reduce the effect of the lecithin, and the substitution of sugar for salt, which might not be too feasible in mayonnaise, probably would prevent that change from taking place.

DR. HAUSER: May I ask a question now? Why does the thing work when you remove the cholesterol? Furthermore, I don't think that the protein involved there is so affected by an increased electrolyte concentration because I can't see, off-hand, at least, how freezing will cause an increase in the electrolyte concentration unless you permit a phenomenon which we call syneresis, namely, a freezing out of the solution, but in regular freezing that won't be the case.

CHAIRMAN SCULL: Dr. Hauser, in the case of the frozen egg yolks that are thawed before they are used, you don't have the same nature of protein that you had before freezing.

DR. HAUSER: That's right.

CHAIRMAN SCULL: You have formed a possible irreversible colloid there and you don't have that protein to work with in holding your emulsion.

DR. HAUSER: That has nothing to do, in my opinion, with electro-concentration. The result of the temperature is naturally caused by denaturing. You could take a protein free of any electrolyte and you would get the same effect.

CHAIRMAN SCULL: In the case of the addition of sugar he uses a non-electrolyte?

DR. HAUSER: Yes.

A MEMBER: May I ask Dr. Hauser this question? In the case of the animal tissues or plant tissues, if you freeze it you freeze it in different ways, but there are some ways of freezing it where you will freeze out the water and what is left would be, for example, the protein of your plant substance. With the electrolyte in a higher concentration, I mean, water would freeze out more or less just as pure water, and the protein which would be quite mixed up in a higher concentration of salt would be worse than before the water was frozen off.

CHAIRMAN SCULL: You don't use eggs that way when you make mayonnaise. As you know, you thaw them out before you use them.

SAME MEMBER: That's right.

DR. HAUSER: In other words, if your point of view is correct, then after thawing out that protein should no longer be able to give the same reactions and properties as it did before. It must be fully coagulated then. Is that so?

SAME MEMBER: No, sir, it's a matter of degree. I don't believe the protein would be fully denatured and coagulated, but it is a matter of concentration. However, the point I brought out, for example, is that some things might be added which can reduce this coagulation and denaturing effect.

DR. GORESLINE: May I add one more thing to the discussion? When egg yolk is frozen there is a difference in concentration at various points of the package. Due to the fact that it does not freeze at a uniform rate, you always find a different concentration in the center of a thirty-pound egg can than you find on the edges. If you thaw that in a relatively short period of time after the egg is frozen, there will be very little difference. After that has been in storage for several months it becomes lumpy and when you thaw it, instead of getting a uniform mixture you get lumpy or gummy egg yolk, and that egg yolk will not make as good mayonnaise. It cannot be used to the same extent as was possible at first. By the addition of about 10% salt to the mayonnaise, or, in fact, if you try to add about the same amount of sugar, which you could not use in mayonnaise, the moisture is prevented and then, because you will have a uniform mixture when frozen, it won't get gummy. The salt acts as a protector to prevent that lumping or gummy moisture effect.

DR. HAUSER: You have made a statement there which I quite frankly believe proves better than anything I was able to present to you tonight how important colloid chemistry is to your field of activities. It shows clearly that in this specific case you are faced with a problem which still has to be worked out to get a satisfactory explanation. You made the statement that the salt acts as a protective colloid. I am not a food technologist, as you know, but, pardon me for saying so, that statement is definitely wrong. What most probably is the case there is that one ion of your salt—and it would have to be ascertained which one it is—acts to increase the electric potential of the colloid involved, and that stabilizes it against what is going on. Now if that is so, I personally think that it would not only be very worth while but extremely interesting to study this phenomenon systematically to ascertain exactly what happens, and, if I may be pardoned for using the scientific term, to determine the changes in the zeta potential or electro-kinetic potential of that system during those additions. I am, however, absolutely convinced that the addition you made has increased your zeta potential.

MR. REHEYL: Dr. Hauser, you mentioned in your talk the influence of homogenization on emulsification. I believe you suggested that because of an increase in the interface by homogenization you should also add more emulsifier. I was always under the impression that the homogenization was a method of emulsifying. I don't know whether I am wrong or not.

DR. HAUSER: As I pointed out, to produce a stable emulsion you must add to the two phases—to the emulsified phase and the other phase which must be an emulsified medium or continuous phase—an agent which will permit the emulsified particles to remain in suspension. To do that you must coat each emulsified particle with a layer of that emulsifying agent. That emulsifying agent must be of such a configuration that one of its ends has a greater affinity for the oil phase and the other one for the water phase. Now, since during homogenization you tremendously increase the interface between those two phases, it is only logical to state that the concentration of an emulsifying agent needed in a homogenized system must be greater to retain its stability.

MR. REHEYL: That all depends on the particle size of the homogenized oil, does it not?

DR. HAUSER: It depends on the particle size of the homogenized oil but as far as I understand the process of homogenization it serves to produce a system with the least conceivable particle size, so that it stays in suspension.

MR. REHEYL: Therefore, you wouldn't need an emulsifier.

DR. HAUSER: Without an emulsifier the particles do not stay in suspension, since they have nothing on their surface which will, when they hit each other, prevent them from coalescing. The particle size alone has no influence on stability. Did I make that clear?

MR. REHEYL: The average particle size in natural milk is 1 to 14 microns and in homogenized milk only 2 microns, which means tremendously increasing the surface area. Now the question is, is there sufficient emulsifying agent on those, let's say, globules, for homogenizing when it is so spread over an increased area, or does the colloidal suspension take place partly because of the reduction in size.

DR. HAUSER: If you allow milk which has not been homogenized to stand, it will cream, which indicates that the gravity of the naturally emulsified particle is lower than that of the dispersion medium. If you take natural rubber latex and let it stand for hours or days it will not cream because it so happens that the particles are very small, and, therefore, Brownian movement counteracts the creaming effect. If you take natural milk and subject it to spray drying, you get a powder which you can scrape up. Put it back in water and you will get milk. If you do the same thing with rubber latex, you can scrape that powder up—you will have a ball of rubber in your hands. That was the situation in 1924, when a young chemist in Munich, Germany, got the idea of analyzing cows' milk and rubber latex for the concentration of the dispersed phase in relation to the amount of protective colloid or emulsifying agent present, and he found that the ratio of the emulsifying agent in the natural rubber latex is a fraction of that in natural milk. So he added another agent, soap, to be specific, to the natural latex and tried again and it worked.

Now in the case where you homogenize natural cows' milk, it contains enough protective agent or emulsifying agent to give you a coating to protect those small particles. However, if you tried the same with milk which has already creamed, it won't work because in creaming a great amount of excess of protein, which acts as an emulsifier, has been settled out in the other portion.

MR. REHEYL: In other words, there is sufficient lecithin or emulsifying agent in that milk as it is produced so that it will sufficiently coat the increased amount of surface?

DR. HAUSER: Yes.

A MEMBER: I think that is all wrong. You made a calculation with regard to the amount of emulsifying protein which was normally on the fat globules of natural milk, which I think demonstrated about 8% of the total available, and after homogenization about 24% has entered into the interface around the fat globules, and that still leaves a very tremendous amount which could be available if needed. It extends the observation which you made.

DR. HAUSER: But to go back again to natural rubber latex, the amount of protein there is already so minute that without even homogenizing—if only for concentration—it just doesn't work any more because it doesn't give you sufficient stability.

CHAIRMAN SCULL: Any more problems? How about trying some other field?

A MEMBER: In the making of ground meats you get coagulation of lamb. Is that a problem is colloidal chemistry, and if so, can it be prevented?

DR. HAUSER: I assume you are married; and although you do not do the cooking at home, why don't you ask the Mrs. to cook you a steak in the best way

she has learned and then to cook you another one where she just keeps it cooking for awhile, and then you taste each. I think you will agree with me that the one which is still slightly on the raw side is the better. What has happened to it? You have in one case coagulated the surface layer which prevents any diffusion from the inside. In the other case you haven't, and the juices are diffused out. It is amazing to me that in so many cooking operations how little attention is being paid to what is really going on there and how much really valuable food, easily digestible food, we just plain waste.

Now, I am Austrian born, as you heard, and the main food in the days I still lived there—they don't get it now—was known as boiled beef, in German, Rindfleisch. Well, if you lived with a family who knew, they would at least save the juice, as they called it, which came out in boiling, and they gave you a very strong, good soup before you got your meat course.

CHAIRMAN SCULL: Are there some more questions? How about some from the starch boys?

DR. HAUSER: In this German situation what they do is to take this waste water in the starch manufacturing process and put that in a huge cylindrical container, and then they blow air through the container, passing it through a very fine sieve to produce lots of bubbles coming up. This waste water contains all the protein of the potato, or whatever you get your starch from, and proteins are, as we call it, capillary active. That means they have a tendency to reduce the surface tension of the water. If a substance reduces the surface tension it can only do that by concentrating in its surface. Therefore, if we have a system of water containing one of these agents, that agent will migrate into the surface until the surface is completely covered with that agent, and the surface layer is actually not water any more but is protein or soap, for example. Now the other molecules, which are in excess of that, stay in the solution but they do not affect the surface tension. However, if we bubble air through we increase that surface or interface by forming bubbles and then, of course, the surface is much greater. So we get more of these proteins to migrate into newly formed surfaces and that forms a foam. Now, it so happens that most proteins will dehydrate in such a condition, which means they form a very stable foam—some people call it coagulation. Now, as this foam rises to a certain level at the top of that container, it is like a good glass of beer where the foam stands over the top. What they do there is this: They have a scraping device and they scrape that foam off and run it on a moving belt which runs right into a dryer. That foam dries. Then it is scraped off as powder and sold as protein, and any housewife who gets that powder—it is like egg powder—puts it in water and there is the protein solution again.

A MEMBER: This is a little defense of American manufacture. Of course, Dr. Hauser has been talking about different brews. A large part of that is corn starch, and there the saving of waste has been almost complete by a somewhat different system than he described but it is a practical enough processing.

DR. HAUSER: Thank you very much for that statement. That makes me feel lots better. I think you will admit that we are not in that industry specifically but we are generally wasting too much.

CHAIRMAN SCULL: Is there anyone interested in what happens to proteins in the frozen food industry? When we freeze foods we do quite a lot of things to our enzymes and we do a lot of things to our proteins, and when we reconstitute the proteins and they are thawed out we don't have what we had when we started. Is there anyone in the frozen food field who would like to pose questions to Dr. Hauser or anyone else in the audience? Dr. Balls is here from the enzyme field. Dr. Balls, can you add to the conversation of the evening?

DR. A. K. BALLS: I can very strongly support Dr. Hauser's contention that the study of colloids is an extremely important occupation. I can speak only as an enzyme chemist, but the sad fact remains that the enzymes are colloids; they are proteins. That means they are water-loving colloids. Like that brain protein that Dr. Hauser referred to a while back—they have quite an affinity for water and less for alcohol. But in a sense, Mr. Chairman, in this consideration of colloids in food technology, enzymes play a rather important role—and out of proportion to the quantity of enzyme material that exists there. On the whole, their presence is not so desirable except in things like cheese making or brewing—something of that sort, where the intent is to alter the original material. Otherwise, I don't know of any enzyme activity that makes us point to it with pride. I think the main thing in food technology is to know how to avoid enzyme activity. It is very true that a little bit of an enzyme catalyst goes a long way.

In studying these things it used to be insisted upon that enzymes be considered as typical colloids. An enzyme action was explained on a purely colloidal basis. I think in more recent times people have got away from that a little bit because it didn't explain that very striking fact known as the specificity of an enzyme. This tends to make people think that enzymes act as individual chemicals. You will recall that Willstätter combined the two ideas, assuming that enzymes had a colloidal carrier, but also a so-called active group that performs a definite chemical reaction.

I think if you work with enzyme proteins very much, you will occasionally run across something that is hard to explain on a purely chemical basis. Come to think of it, we ran across such a thing in our own laboratory. I will tell you about it. If anybody has any bright ideas on the subject, I will be more than grateful to get them.

Lipase is a water soluble enzyme whose function is to hydrolyze fats which are quite insoluble in water. So the relation of surface to volume of a fat particle must be critical in lipolysis otherwise it wouldn't go very well. We were interested in this emulsification and we decided to see what happened when the system was made colder and colder. Of course it went slower and slower. When we finally froze the thing, we had no reason to suppose that we would find any great amount of enzyme action. We froze these systems as hard as a brick, but after several days in the cold, we observed a very considerable amount of fat hyrolysis; very much more than you would get in a controlled piece of frozen fat emulsion which did not contain the added enzyme. So I see no help for it but to blame the enzyme. I must say that I am not in a position to explain the observation on the basis of straight chemistry.

DR. HAUSER: I may answer that your last statement would prove my point of view. Straight chemistry alone does not do the trick. I would also like to add that if you freeze certain foodstuffs there are certain reactions taking place which can be avoided very definitely, as was mentioned at the outset of a talk which was given this meeting by a very dear friend of mine, who is sitting right here. I am referring to Mr. Bradley Dewey. He has developed a process which overcomes this problem beautifully, and it would be interesting if you could study your enzyme work, particularly under those conditions—and I am referring to the freezing of foodstuffs—in a closed bag, known as the Cryo-Vac Process, and I think you will find that no change has taken place.

DR. BALLS: I don't know, Mr. Chairman. Why do you think that covering the thing with a bag would make any difference?

DR. HAUSER: Because if you cover it under the conditions of that process the equilibrium of your system is not changed, whereas if you don't and put it in a

refrigerator it is changed tremendously, and colloids depend on the equilibrium condition of surfaces.

DR. BALLS: Don't think we didn't stopper these tubes. They weren't exposed to air and allowed to evaporate.

DR. HAUSER: Were the tubes absolutely full?

DR. BALLS: Yes.

DR. HAUSER: I am not an enzyme technologist, but all I can say now is that it proves once more that straight chemistry is insufficient to help in this entire field.

DR. BALLS: That's true.

MR. HENNING: I wonder in freezing vegetables, et cetera, if we used this bag that Dr. Hauser speaks of, if we could do away with the blanching.

CHAIRMAN SCULL: Would not blanching before freezing still be necessary, Dr. Balls?

DR. BALLS: I have not tried it but my guess would be that it is necessary. Much experience points that way.

CHAIRMAN SCULL: Perhaps a rubber bag somehow allows volume relations to be at play, which you don't have in your glass tube. I couldn't answer that either.

Well, we have talked about detergents and mayonnaise and starch. What other fields are represented here? Would anyone like to bring up some other problems? I think we ought to get a lot of these problems brought up here and at least get the germ started.

It might be a good idea to have colloid symposiums in your various local sections when you go back. At least, you could have a couple of talks during the year in various local sections of the IFT and see if you can approach or get your thinking oriented along the lines of thinking about surface relations. Any more questions or discussion?

MR. JONES: I don't think we can do away with blanching before freezing. We tried that.

CHAIRMAN SCULL: We found out through a sad experience in this country that it was necessary to inactivate the enzymes by heat, too.

When we talk about additions of protective colloids and enzyme agents, if we are marketing a product we should keep in mind that it is best to check with the Food, Drug, and Cosmetic Departments about standard of identity to see whether we are doing a permissible thing.

MR. A. H. WARTH: Do the gases exhibit similar colloidal phenomena to the solids in liquid dispersers—for instance, carbon dioxide in water, excluding the phenomenon of foam on beer and other things.

DR. HAUSER: If the carbon dioxide is present in the form of bubbles in the colloidal dimensions it will exhibit certain typical phenomena.

MR. WARTH: For instance, if we take the colloidal dispersion of carbon and add just a drop or two of that to a liter of a solution of carbon dioxide and water, we get rather an explosive force of gases immediately thrown out of the solution. How do you account for that?

DR. HAUSER: Well, do you mean when you add the carbon black—and you say it is of colloidal dimensions?

MR. WARTH: Yes, a very small amount to a supersaturated, quiet solution of carbon dioxide and water.

DR. HAUSER: Then the carbon dioxide plus the carbon black goes up into the surface?

MR. WARTH: Yes.

DR. HAUSER: Plus the carbon black—that goes with it?

MR. WARTH: Yes.

DR. HAUSER: That is an adsorption phenomenon. You have a tremendous surface available on your carbon black, and what happens there is that the O of the CO_2 adsorbs on the C ion in that surface layer. Now, for example, that has nothing to do with food technology but in a heterogeneous catalysis using nickel, for example. Take a polished nickel surface—and you want to make carbon dioxide by introducing carbon monoxide and oxygen—nothing would happen at all. But if you take a nickel powder or nickel which has been made porous by spraying hot metal, you will get a tremendous carbon dioxide production immediately at fairly high temperatures, if you introduce your oxygen first; but if you introduce carbon dioxide first it won't work. That is a straight-forward surface phenomenon because the adsorption of the O_2Ni ion is stronger and, therefore, holds longer at elevated temperatures. If you have the CO tacked on, the O can't get there because it is pushed away. Finally, however, they get together.

DR. REICH: I believe when you carry that out with carbon dioxide and you adsorb carbonate and make dicarbonate out of it, adsorption is very slow. However, if you throw into that some sugar or glycerine the adsorption is much greater and you get a much more rapid conversion of dicarbonate into carbon.

CHAIRMAN SCULL: I think from the discussions this evening we are all satisfied that colloids play an important part in food production. We cannot overlook the colloid field. When we leave here I am sure we will look into the field a little more closely than we have in the past. The discussions have brought out very forcibly that it is not just enough to be a chemist or a physicist. We must consider this realm of small dimensions, small volumes, and large surface areas.

Are there any more questions from the floor? (No response.)

Before we adjourn I should like to extend our thanks to Dr. Hauser for his paper and informative discussion.

I call this meeting closed.

POSSIBLE PRACTICAL APPLICATIONS OF HISTOLOGICAL RESEARCH TO FOOD PROCESSING[a]

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The author points out the possibilities of solving some of the unanswered problems in food processing by means of a histological approach. Morphological data thus obtained will eventually be correlated with physical data. Several examples, with photomicrographs, are given.

The existing literature on the actual microscopic structure and microchemical composition of the various biological materials which are used as foods, and the changes which these may undergo in processing is very limited.

During the recent war some important contributions were made by cooperative projects of the Botany, Truck Crops, and Pomology and Food Technology Divisions of the University of California, *(2, 4, 14, 15, 16)* and by Reeve *(6, 7, 8, 9)* of the Western Regional Research Laboratory of the U. S. Department of Agriculture. These studies have mainly dealt with the effect of blanching and dehydration upon the starch, carotene, and intercellular air of the tissues. At Iowa Lowe *(3)* has been able to show a definite relationship between quality and histological structure of poultry. With regard to frozen foods, the microscopic work so far recorded has been mainly directed toward a study of the size, distribution, and structure of the ice crystals. (See Tressler and Evers *(13)* for general discussion.)

While all of these researches have made valuable contributions, there still remain many unanswered problems in food processing both in the fields of freezing and dehydration, and probably also in canning and pickling, which may be better understood if a study were made of the histological structure and chemical and physical nature of the tissues making up our common processed foods.

One important problem in frozen foods is the apparent toughening of the skins. *Reeve (10, 11, 12)* has made a careful study of the structure and chemical nature of the skins of peas and lima beans which should serve as a valuable background and guide for possible practical treatments of these vegetables which might tenderize the skins of the frozen product.

Most packers of frozen fruits are familiar with the fact that the skins of frozen apricots are unpleasantly tough, making them difficult to cut with a spoon or to chew, while canned or dried apricots present no such problem. The question naturally arises: "Is this an actual toughening of the skin or does the frozen apricot skin only seem tougher by contrast with the softer tissues of the flesh which has become flabby as a result of freezing?"

This question may be partially answered by Table 1. The readings given in the table were made on the Candee and Boggs *(1)* penetrometer which measures the relative weights required to penetrate pieces of tissue. The figures do not represent absolute weights, but they are all comparable because the load was the same throughout the tests. All of the fruit used for the data in Table 1 was from a single lot of Royal apricots grown at the University's pomological orchard in Winters, California. A study of the table shows that freshly frozen apricot skins did not require more weight for penetration than fresh untreated skins, but were more variable. However, after four and a half months of storage at 0° F. (— 17.8° C.), the penetrometer readings were markedly lower, yet subjective taste tests of this fruit still

[a] Paper presented at the Annual Meeting Northern California Section, of the Institute of Food Technologists, Dec. 4, 1947.

TABLE 1

Objective Data on the Texture of Apricot Skins Processed in Different Ways

	Penetrometer Readings[1] (Averages of 100 readings)
1. Fresh apricot skin (mainly central portions)	1.09 ± .16
2. Fresh apricot skin (stem end)	1.28 ± .17
3. Fresh apricot skin (blossom end)	1.03 ± .11
4. Quick frozen apricot skin (freshly frozen)	1.09 ± .27
5. Frozen apricot skin (4½ mo. old)	.59 ± .12
6. Canned apricot skin (freshly canned)	.71 ± .51
7. Canned apricot skin (4½ mo. old)	.31 ± .11
8. Dehydrated apricot skin (3½ mo. after dehydration)	.33 ± .12

[1] These represent relative weights required to penetrate the tissues. The figures are arbitrary, but comparable within the series.

showed tough skins. Canned and dehydrated apricots were more tender than frozen, but when first canned they were highly variable. After storage at room temperature for 4½ months they were more tender, and less variable.

These objective physical data are eventually to be correlated with morphological data which are as yet quite incomplete. The studies so far undertaken have shown that apricot skins contain a vascular system somewhat comparable to the veinlets in most leaves, and that in this system there are very interesting sclereids. Figure 1 shows a sclereid which has been macerated from frozen apricot skin by Priestley's method *(5)*. These terminal vascular cells, or sclereids, are extremely tough and can go unchanged through some rather harsh chemical treatments. In the frozen apricot skin, it may be these strong vascular elements which cause the skin to be so difficult to cut or chew, even though the total physical toughness is no greater than that of the fresh skin.

A fresh ripe peach or apricot does not appear to have tough stringy vascular tissues, but after it has been frozen and thawed, even the fleshy parts often have very noticeable stringly vascular strands. The same thing is true of certain vegetables such as asparagus and even squash. When these vegetables are cooked fresh, the entire tissue mass cooks to a fairly even tenderness (provided the vegetable is harvested at the proper maturity) but a frozen vegetable of this class (even of optimum quality) always has noticeable stringiness when cooked. The question is: "Does the vascular tissue actually toughen upon freezing, or is it apparent merely because the other tissues have lost so much more of their original rigidity after freezing?"

When we turn from freezing to dehydration problems, we are still faced with skin toughness. Recently the industry has become strongly aware of tough skins in dehydrated prunes. Table 2 shows penetrometer data on prunes which were treated as indicated. The first four samples show varietal differences among the common California prunes. The other data show the effect of various methods of processing upon the toughness of French prune skins. The two most effective tenderizing procedures were lye dipping and steaming prior to dehydration. Neither of these yielded a very attractive finished product, mainly because of resulting undesirable color changes in the skin. Microscopic study of the prune skin has shown that the pigments are present in only one or two surface layers of cells. This color is very vulnerable to changes by steaming and lye dipping. Among the processes listed in Table 2, the best for quality of freshly dehydrated product was treatment with water and steam subsequent to complete dehydration.

Figures 2, 3, and 4, showing three varieties of prune skins were photographed with low power magnification from slides prepared by the clearing technique, which

TABLE 2

Objective Data on the Texture of Prune Skins Processed in Different Ways

	Penetrometer Readings[1] (Averages of 50 readings)
1. Fresh Imperial prune	1.10 ± .22
2. Fresh Sugar prune	1.07 ± .23
3. Fresh Robe de Sargent Prune	1.16 ± .22
4. Fresh French prune	1.84 ± .26
5. French (½ dried)	1.89 ± .27
6. French (½ dried and steamed 10 min.)	1.30 ± .19
7. French (½ dried and steamed 10 min. and then dehydrated to 20% moisture)	1.78 ± .28
8. French (dehydrated to 20% moisture)	2.01 ± .24
9. French (dehydrated to 20% moisture and water and steam processed)	1.09 ± .19
10. French prunes (lye dipped and dehydrated)	.75 ± .29
11. French prunes (steamed and dehydrated)	.80 ± .30

[1] These represent relative weights required to penetrate the tissues. The figures are arbitrary, but comparable within the series.

involves removal of pigments by treatment with 5 percent NaOH in an incubator, (at 30° C.), followed by washing, staining with safranin, dehydrating with alcohol, clearing in xylene, and mounting in Canada balsam. The interesting feature of the

FIG. 1. Macerated apricot skin, showing specialized vascular cells (sclereids). X250

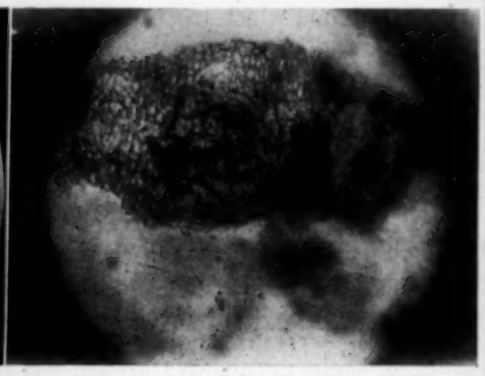

FIG. 2. Cleared and safranin stained skin of fresh French prune. X52

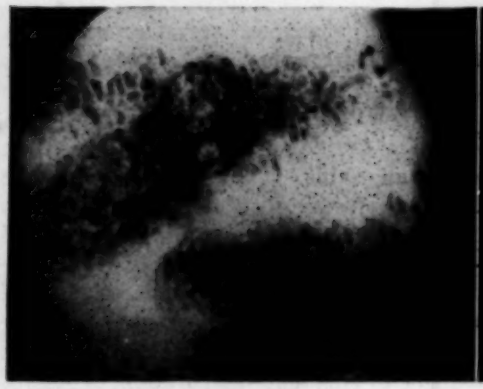

FIG. 3. Cleared and safranin stained skin of fresh Imperial prune. X52

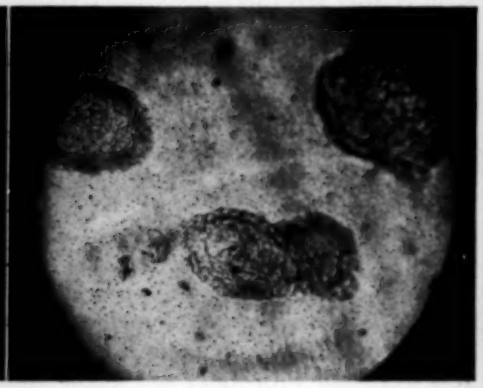

FIG. 4. Cleared and safranin stained skin of fresh Sugar prune. X52

skins of all varieties shown is the mottled effect, caused by areas made up of small, thick-walled, densely staining cells, interspersed with areas having larger, thin-walled, unstained cells (the actual cell limits of these parts of the skins do not show under the intense illumination used in taking the photomicrographs.).

Turning attention from prunes to figs, we find that there is not only the problem of skin texture, but also of pigment in the black fig. Most black figs are left on the trees until they are quite dry (close to 20 percent moisture) and then processed into paste to be used mainly in fig bars. The pigment in the dark skins becomes a problem in discoloration of the entire product. Figures 5, 6, and 7 show some

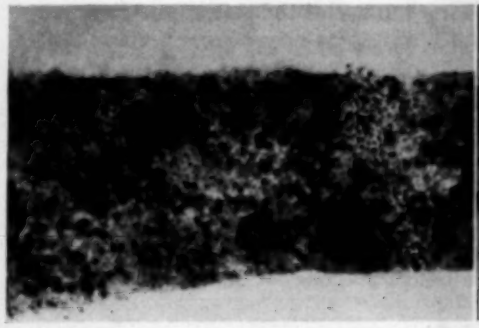

FIG. 5. Surface view of skin of Black Mission fig, showing distribution of pigmented cells. X100

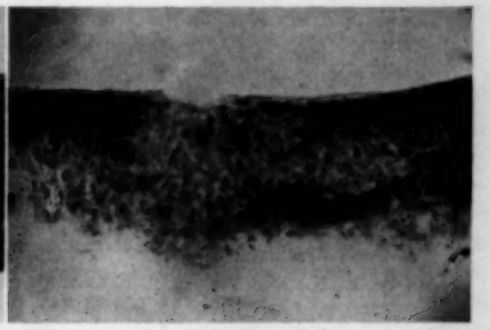

FIG. 6. Cross section of skin of Black Mission fig, showing pigmented cells mainly just at the surface. X100.

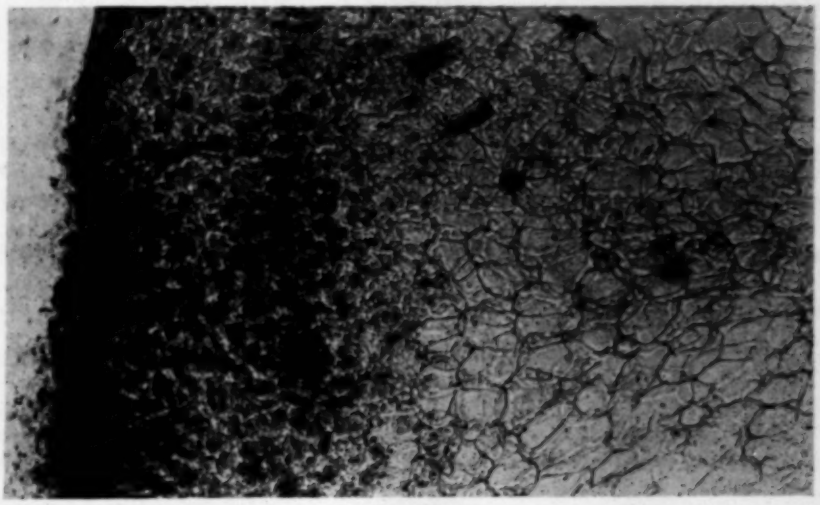

FIG. 7. Cross section of naturally dried Black Mission fig (as ordinarily harvested for dried fig paste). Approx. X300.

interesting observations which have been made on distribution of pigments in the Black Mission fig skin. Figure 5 is a surface view of a fresh ripe (but not shriveled) fig. It shows that pigment was present in somewhat less than half of the surface cells. Figure 6 (the cross section of the same fresh fig skin) indicates the additional fact that pigment is present only in the upper layer or two of cells. Figure 7 shows

a cross section of a dry Black Mission fig, as ordinarily harvested for paste manufacture. This reveals how the pigments have diffused down into deeper lying tissues.

The above and numerous other problems can be studied from this histological point of view. Even if the results should be negative in some cases, we will at least know that the answer is to be sought elsewhere and will not be leaving an entire avenue of research unexplored.

ACKNOWLEDGMENT

The author expresses her sincere appreciation to Miss Mildred Boggs of the Western Regional Research Laboratory, U. S. Department of Agriculture, Albany, California, for her kind cooperation in allowing the use of the penetrometer.

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COMMENTS ON STANDARDIZATION OF TEST METHODS FOR CATIONIC SURFACE ACTIVE AGENTS

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Caution is urged in the phenol coefficient determination and in the usage of proper terminology for the action of the quaternary ammonium compounds.

Bactericidal activity is found with straight chain aliphatic, with aromatic and heterocyclic quaternary compounds, and also with primary amines, sulfonium bases, phenols, carboxylic acids, alkyl and aryl sulfates, and sulfonates, simple and substituted.

Ever since Lister the English physician used phenol as a spray in preoperative technique resulting in a decrease in the number of post-operative infections, usage and tradition led to the use of phenol as a standard for comparison. In later years, when new compounds were found to be "germicidal," the term phenol coefficient was introduced and became standard. There have been many adaptations and modifications of the original technic devised by Rideal and Walker, but in principle the current F. D. A. method is the same. In general the latter gave fair comparison when phenolic preparations were tested but when the method was applied to mercurials, oxidizing substances and more recently, the quaternary ammonium compounds, comparison frequently ceased to exist.

Ever since Domagk in 1935 stimulated research on quaternary ammonium compounds there have been indications that the official F. D. A. method developed by Ruehle-Brewer (1931) does not always lead to reproducible results when applied to highly effective germicides. *(1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 17, 19, 20, 22)*. On the other hand Anderson and Mallmann *(1)* minimized discrepancies in the hands of skillful investigators, and recommended a member of the class as a reference, while Barry and Puetzer *(3)* and Mueller and his co-workers *(15)* brought out the fact that the results and method of laboratory testing were of less importance to testing in actual use. This latter point was also emphasized by Mallmann *(14)*.

Unfortunately some literature and specifically sales propaganda on quaternaries emphasized high bactericidal dilutions versus certain organisms, the results of which were as limited in value as the phenol coefficient test was with effective quaternary compounds. Since there was no general standard method in the evaluation of the quaternary ammonium compounds in the laboratory, germicidal values reported for these compounds were bound to be subject to considerable discussion. Several investigators *(2, 10, 14)* realized that it was time to determine whether one was dealing with disinfectants or antiseptics or both, recognize the limitations of these compounds, recognize the limitations of older methods of testing (such as the p. c. test) and standardize a procedure with regard to use application *(14, 15)*.

There seems to be two major items to consider—method of testing in the laboratory and actual testing in the field—bactericidal in the laboratory and bacteriostasis in the field. Expressed in a different manner, with disinfectants we can expect a killing of different species of bacteria at about the same rate, but when so-labeled, therapeutic agents or antiseptics are applied, there results a selectivity of action—some bacteria are resistant while others are susceptible. The quaternary compounds can very well fall into the class of compounds which are selective.

Speaking of selectivity in general, we are referring to gram-positive and gram-negative organisms. In high concentrations quaternaries as disinfectants are bactericidal, while in low concentrations they may be considered as antiseptics, bactericidal and/or bacteriostatic. Many times the terms "disinfectant" and "antiseptic" are used too glibly. In general, disinfectants are chemicals usually applied to inanimate objects and are bactericidal with less emphasis on toxic hazard. As an antiseptic, chemicals or biologics which are applied to animate objects are effective in high dilution and have a minimum of toxic hazard.

One of the difficulties in the past has been the comparison of a wide variety of types of compounds including the quaternaries, by various methods. Unfortunately at times the methods of testing and comparison have emphasized the superiority of one product over another rather than an improvement upon the method of testing.

The main difficulty in the use of glass beads, rods, filter paper, etc. was an increase of practical difficulties in the mechanics of testing, increased numbers of dilutions to be prepared and large quantities of media necessary. Armbruster and Ridemour *(2)* were successful in finding a suitable means by which a true bactericidal rather than a bacteriostatic end-point at high dilutions could be attained with the quaternaries. They used thioglycolate medium, Azolectin (a purified phosphatide) and Tween 80 (polyoxyalkylene sorbitan monolaurate) and agar with excellent results in eliminating bacteriostasis. They emphasized the use of a small number of organisms; but would not a compound be expected to be more efficient in the presence of a small number of organisms?

For the past several years this author has been interested in testing methods for the quaternaries. Many of the methods proposed by various investigators were tried with varying degrees of success dependent upon several factors such as: composition of medium, neutralizers, order of procedure, dilutions, resistance of organism, time and temperature of incubation, subculturing, size of inoculum, pH of medium, etc.

Realizing the number of variables that would be encountered if an entirely new departure from the present F. D. A. method were employed (U. S. D. A. Circ. 198) a minimum of deviation was used. The following procedure gave consistent results: In the medication tube was placed 0.5 ml. of a 24 hours culture (*Eberthella typhosa*, Hopkins strain, or *Staphylococcus aureus*, No. 209 A. T. C. C.). To this was added a 5 ml. dilution of the compound, the dilution being prepared with distilled water containing 0.5% Tween 80.* After 5 and 10 minutes exposure at 20° C. or 37° C., 0.1 ml. was transferred from the medication tube to thioglycolate broth and then incubated for 72 hours. Subtransfers were made at the end of 30 minutes to detect bacteriostasis, although this appears to be unnecessary since bacteriostasis was rarely encountered.

The concentration of inoculum was important in that if less than 0.5 ml. of a 24 hour culture were added to 5 ml. of diluted medication, higher effective dilutions of the compound resulted. Similarly if less than 0.1 ml. of transfer to thioglycolate broth were used, there also resulted an apparently more effective compound, but with accompanying variation in end-points. Occasionally, bacteriostasis would appear just below the end points, but by incubating for 72 hours, subculturing was found to be unnecessary.

The addition of organisms to the medication tube prior to the addition of the diluted compound tended to reduce skips due to carelessness such as when the pipette touched the wall of the test tube.

*Tween 80—Atlas Powder Co.

At a disinfectant symposium of the NAIDM meeting held in Chicago, June 1947, the following points were stressed:

1. Mueller, of Mass. State College, emphasized actual working conditions rather than the F. D. A. method.
2. Klinek, of Winthrop, brought out the expectancy of variation because of small numbers of surviving bacteria, but whose importance was questionable.
3. James, of James Laboratory, felt that soap as a neutralizer would eliminate the problems of bacteriostasis in testing.
4. Cade, of Givauden-Delawanna, emphasized two problems — 100% kill and 99% + kill.

A review of literature amply shows that the entire situation of quaternary compound testing has been one of confusion, and at present it appears to be in a state of flux. However, a considerable amount of good laboratory data has been accumulated.

For some time the Insecticide Division of the U. S. D. A. has been checking various suggested procedures against the official AOAC phenol coefficient method with each official sample of quaternary ammonium germicide examined. In the final analysis, any one method or several methods to be finally adopted for use in commercial testing must have the government stamp of approval. From these data together with data submitted to Dr. L. S. Stuart of the Insecticide Division, Dept. of Agriculture, by the N. A. I. D. M. Disinfectant Scientific Committee as a result of a collaborative testing program with 18 cooperative laboratories, a tentative routine has been established and will be employed.

The following points of interest were brought out from these investigations:

(1) The effect of various brands of peptones and trypticase in the culture medium on quaternaries was not consistent.
(2) The effect of serum medium seemed to be one of a quantitative reaction between the serum and the quaternary, reducing available germicide, rather than a change in cell resistance.
(3) Where the coefficient values were greater than 7.5 (ratio of protein in inoculum and germicide) the organic material appeared to be significant and probably a major variant in the critical concentration and death time.
(4) "Use dilution" by "carrier sampling" method gave dilutions of 2.3 X higher than the "safe use dilution" method of the FDA.
(5) Results with *E. typhosa* showed a wider variation than with *S. aureus*, and by the use of dilution or carrier test, *E. typhosa* seemed to be a poor test organism.
(6) Dilution skips were more frequent than time skips, and 72 hours incubation tended to eliminate skips.
(7) Use of Tween 80 + Azolectin tended to reduce bacteriostasis, although differences in ingredients on preparing Letheen Broth seemed to account for discrepancies.

The exact details of the procedure appeared in the September issue of Soap and Sanitary Chemicals.

In summation a portion of a recent letter received from Dr. Stuart on these details is quoted:

"Briefly they (the tests) consist of determining the phenol coefficient by the official A. O. A. C. method modified to stipulate vigorous shaking before each interval transfer and the use of "Letheen Broth" in lieu of F. D. A. broth for subculturing. The safe use dilution as calculated by multiplying the coefficient, found against *E. typhosa* in this presumptive test, by 20 is then checked in a confirmative use dilution test using *S. aureus* 209 as the test organism, carrier sampling, a 10 min. exposure interval at 20° C. (68° F.), and "Letheen Broth" for subculturing."

"We believe that the phenol coefficient test as it has been modified still provides us with the best presumptive index to the germicidal activity of materials. The final answer can only be provided through actual use, or simulated use tests. With

surface active materials or any preparations where the nature of the death time curve is such that it is difficult to arrive at an exact death time, it would seem essential to have a number of standardized simulated use tests for confirmatory purposes."

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Industrial and Legal Viewpoints

RELATION OF TECHNOLOGY TO SOUND COMPANY FINANCING[1]

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When I was asked to take part in your program, I was somewhat puzzled as to how I could say anything effective on the relation of food technology to sound company financing in the presence of this audience who are experts in food technology about which I know so little. Your program committee eased the strain somewhat when they allowed me to change the subject and to discuss the relation of *technology* to sound company financing. I do not consider that company financing in the food industry is governed by any different set of fundamentals than is company financing in any other manufacturing business, although, of course, each type of business has peculiarities which must be known and understood if we want to chart its future intelligently.

While I claim no particular knowledge regarding the food industry, I am deeply impressed with the fact that the production and distribution of food has always been and must continue to be one of the most important functions in the world. Success in the struggle for survival throughout recorded history has been measured almost exactly by the development of food supplies, and those who have given to mankind improved means of supplying the human body with sustenance have been among our greatest benefactors.

Food technology is not a new thing, although I suspect the advances made in the last few years are even more significant than most of us realize.

Within a few miles of this place was born in humble circumstances a man of many-sided abilities and characteristics. The Woburn boy who was known here in Colonial times as Benjamin Thompson became one of the world's greatest scientists and one of the world's greatest masters of military strategy. As Count Rumford, a Count of the Holy Roman Empire, he served humanity in many respects. Probably his greatest achievement was derived from his study of the properties of heat and his development of what we now know as the baking oven. Its purpose was to aid mankind by improving methods of preparing food, particularly bread. He was, therefore in his time, the 18th Century, a great technologist in the field of food preparation.

Christopher Ludwick, a German baker from Philadelphia, was credited by General Washington in our Revolution with a tremendous contribution to the Patriot cause by his development of methods of preparing bread and other foodstuffs for the Continental Army. All through history food has been as great a determinant of actual victory as has any other of the elements of military strategy. Napoleon's defeat in Russia according to Caulaincourt was almost entirely attributable to lack of food, and I suspect our victory in the latest war is as much attributable to our better food supply as it is to some of the other elements ordinarily considered.

Persons who supply money to industry, whether as investors in equity or purchasers of obligations, are not only concerned with the ordinary items of net worth, past and present earning power, and proper working capital coverage, but also are concerned with the longevity of the business as demonstrated by its ability to meet the vicissitudes of time. New England's industrial history is full of examples

[1] Presented before the Seventh Annual Food Conference, Boston, Mass., June 2, 1947.

of companies which were exceedingly prosperous but which, owing to unwillingness to meet the changing conditions, did not survive. Research, experimentation and technology are the evidences of wise management and the insurance which investors look for to provide the elements necessary for institutional survival.

If there is any one lesson to be gained by the study of industry as it has developed in this industrial area, it is the lesson of continual change. Nothing stands still. No person can ever say "I have reached the goal of industrial perfection" in any line. The frontier in this respect forever travels ahead of us into the distant future. One goal gained leads to the possibility of a dozen more. It is like the experience of the traveler in the mountainous country who always wants to see what is on the other side of the hill. When he reaches the top of one hill, a succession of other hills, often higher and more difficult of ascent, stretch away into the distance. So it is with the technologist and scientist who are engaged in research, whether for new products, or markets which will buy new products or research in human perceptions now more necessary than ever in successful industrial management.

Startling as have been the accomplishments of the past, it will not be surprising if they seem small compared with those of the future. No matter how firmly established and successful in the present, each industry depends on research to hold its place in the competitive struggle of the future. That is why the accomplishments of private industry in a competitive world are fraught with uncertainty. This danger of failure, however, leads to higher accomplishments than does the comparatively riskless endeavor of the totalitarian state.

The history of New England industry is a history of the use of imagination, experimentation and ingenuity. Through the years since industry was born in this country, following the acceptance by the 13 Colonies of the Non-importation Agreement, this section has made conquest of its fortunes by the ingenious abilities of its citizens to manufacture and sell the products of manufacture. With less of nature's bounty in the supply of raw materials than most sections of the country, New England has succeeded to date in maintaining a higher standard of living for its citizens than the national average. The per capita income of New England has led the nation because of the productivity of its industries. It is a fact too little realized that New England with 2.2 per cent of the land area of the United States and 6.4 per cent of its population produced over 9 per cent of the commodities necessary for the successful conclusion of World War II.

We claim here no superiority in patriotic endeavor, but we do have a section more nearly reaching maturity in industrialization than the rest of the country. The "know how" and habit of successful business endeavor, whether in manufacture or trade, has characterized the inhabitants of this area from the days of the early settlements. The Yankee clock-maker who succeeded in making good clocks with wooden works when the British embargo shut off the supply of metals was a technologist in his time as important as some of our scientists today.

The necessity of maintaining a place in the world markets has been the spur which made men use their wits and native genius to produce new products of continuing higher quality and at less cost through the years. The country grew rich because our research was as good as or better than that of our competitors. As the world has grown smaller through improved communication and transportation, the necessity for research in industry has intensified. It will not be enough to produce good merchandise in the times ahead, and market research becomes as much a necessity as the fundamental research which has had so much attention.

Technological progress depends on the increased use and development of new machines, economy of raw materials, improvement in products, plant and plant

organization, and more efficient use of manpower. All these and many more developments are necessary to produce the certainty of continuation which the investor looks for.

In looking toward the future in industrial endeavor the human element having to do with the relation of employer, manager and employee is more and more important. Research in these matters is fully as important as any other types of research which we have discussed. No industry presents a satisfactory picture for the investor which is not able to maintain good relations with its employees. The situation has been clouded by all sorts of mis-applications of "justice," politics and the like, but in the long run it is necessary that the human equation presented by the employment of large numbers of people in productive enterprise be solved in an understanding and just manner. As education increases and standards of living improve, workers are entitled to expect more sensible consideration than they received in those times when industry was young and many workers were recent arrivals from the farm or from overseas. On the other hand workers must understand that there is a limit beyond which management and ownership cannot go. The opportunity of the wage-earner to obtain security through continuous employment, followed by a fair retirement system for the declining years of life, is entirely dependent on a profitable industrial history in each business institution. The understanding that Government is more of a consumer of wealth than a producer, that the only production of wealth is through the production of goods and services has not been fully achieved by the American people.

American workers have been misled in part by their own leadership and in part by others, in most instances well meaning people, who have succeeded in making them think that they should look to Government for the alleviation of their ills, whether actual or imagined. I do not feel that industry itself has done a good job in selling those workers on whom it depends for manufactures the idea that their future and their opportunities can only be protected by continuing and sustained efforts in the fields of technological experiments and research. As industrial union leadership becomes wiser, more experienced and more reliable, the opportunity for salesmanship on the part of industrial management in this respect will be enhanced.

I know you will all join with me in the belief that the American people are sound, reliable and decent. They have repeatedly shown those attributes as crisis after crisis has been met. The reawakening of individual responsibility which was necessary to the winning of the war must not be lost in time of peace. An appreciation of the assets to be developed by technological endeavor compared to the destructive results of race and class conflict should be easy to sell in a country which has the advantage of highly developed types of communication available here.

In the world of tomorrow illiteracy should be almost unknown and the industrialist, backed by the accomplishments of scientific endeavor on the part of the technologists, should be able to get—and must insist on getting—a fair hearing and a fair understanding. Such fair understanding presupposes that those things relating to industry which are reasonable and just can be sold to an intelligent people.

METHODS OF OBTAINING COSTS OF RESEARCH PROJECTS *

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Mr. Rector points out why research accounting is necessary, who should participate in it, and how it should be done. He shows that research accounting has an important relationship to management, and to control of research and development operations. The method proposed is comparatively simple and is being used successfully by General Foods Corporation.

This subject relates to accounting practices in connection with the conduct of research, and certainly cannot qualify as a very interesting subject of itself. Most research directors look upon research accounting as a necessary evil. It is, however, an extremely necessary evil and not necessarily as evil as it may seem.

For the purpose of making this point, let us submit the matter of research accounting to the standard test of any project:

1. Why do it?
2. Why do it now?
3. Who is going to do it?
4. How is it going to be done?

Let us consider this test of the project in relation to the three main criteria of successful operation of any enterprise:

1. The enterprise must have good organization.
2. It must have good planning.
3. It must have good executive control.

In this day and age, technologists need no selling on the necessity of good organization in a research and development department. All technologists have learned that the research and development department should be organized at least as well as any other department of the business. They know that they must have clear lines of authority free from conflict. They also know that responsibility and authority must go together.

The same can be said for good planning in a research and development organization. No activity in a corporation needs better planning than the research function, and in industrial research the planning must be participated in, not only by the research organization, but by general management as well.

Given good organization and good planning, the third element necessary to assure smooth operation and efficiency over a long period is good executive control of the research and develeopment function, again not only by the research director, but also by general management. General management can help with organization. It can participate in planning. In both of these activities, however, the amount of help that general management can give its Research and Development Department is almost directly proportional to the amount of financial control information it has at its disposal.

Research accounting, therefore, should by all means be done. It is the only effective way of giving the research director financial control of his operation and is also the only effective way of keeping general management in full touch with what is going on in its research and development department.

General management, with accurate figures in front of it, is also greatly aided in its function of helping in the problems of organization and planning.

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If, at this point, it can be assumed that research accounting should be done, it seems obvious that accounting should be put into effect as soon as possible. In other words, it should be done now.

This brings us to the third test—Who is going to do research accounting? The answer is that the whole organization must participate in it.

General management must participate in research accounting first by insisting that it must be done, and second, by supplying the talents of its general accounting department in setting up the system. The research director, as executive in charge of all research and development activities, must take the responsibility of installing the system after it has been planned in cooperation with the accounting department and seeing to it that it works. This often takes a lot of doing, particularly when the members of the research organization have had no previous experience with research accounting. The actual accounting work should, of course, be done by a skilled accountant, but even the most skilled accountant will need a lot of help in dovetailing his accounting knowledge with the problems which are peculiar to research and development.

Back in the days when card index systems were first being installed in business, two businessmen met on a street corner and one said, "I hear you have installed a new card index system. How does it work?" The other businessman said, "Fine, great, we are very much pleased with it." Businessman Number One said, "Well, how is business generally?" His friend said, "Oh, business has gone to Hell. We are much too busy running the card index system to attend to business."

There is a lesson to be learned from this little conversation. Obviously, if a research laboratory will operate better without an accounting system, then by all means, don't have an accounting system. In any event, don't let the accounting system become an object in itself. Insist that it be set up in such a way as to be an effective tool of organization, planning, and particularly of executive control.

Now, it has been decided who is going to do this job. General management has a part in it. It contributes the executive push to get it going, if this is needed. It contributes the advice and services of its accounting department in setting up the system. The research director has a part. He must sell the research organization on the necessity of having a system and participating in its operation. This is very important, because if the organization is not sold on the system, it can do a very fine job of sabotaging it. The research director must pick the right kind of an accountant and give him the right kind of tools to work with and help the accountant to develop a system of control reports, which will enable the research director and the general management to know what is going on financially at all times in the research and development picture.

Now comes the question of "How is this job going to be done?" For convenience, this phase of the subject can be broken down into four principal divisions:

(1) Research and development budgets.
(2) Research and development programs.
(3) Project accounting practices.
(4) Financial reporting.

Before going into the subject of budgeting, we can assume that general management, of which the research director should be a part, has agreed upon research policies and objectives covering:

(1) In what fields does the Company wish to do research?
(2) How is this research to be apportioned between fundamental work, new product work and old product improvement work?
(3) How much money can the firm afford to invest in research annually?

When these important points have been settled, the research director can take the lead, in cooperation with general management, in planning his budget for the year.

After he has been allocated so many dollars to be spent in research and with this amount fixed fairly definitely, the research director must budget accordingly. Under present conditions he can estimate roughly that his overall research cost will be somewhere in the neighborhood of $6,000 per year per person employed in research. This may sound like a low figure until it is considered that this sum includes everyone from the office boy and the laboratory assistant up to the director of the laboratory. Dividing the annual appropriation by $6,000, therefore, gives a rough indication to the man responsible for setting up a research and development budget of the total number of personnel he can afford to have in his organization. In technological food research about 40% of the research group will ordinarily be technically trained and 60% non-technically trained. If the budget allows for a total personnel of 50, then the research director can count on a group of about 20 technical graduates.

Of his total expenditure, about two-thirds will be for payroll and the remainder for supplies and fixed expenses. It should be recognized, of course, that these are only the roughest of guides, but it is believed that they will be found useful in preliminary food research budgeting.

Many of the items of expense for a research laboratory can be determined quite definitely in advance. In others, the experience factor is important, and for the first year the laboratory director can expect to miss his budgets, made on a quarterly basis a month or so in advance, by from five to ten percent. As time goes on, however, the experience factor will come more and more into play and research and development budgets should be accurate, on a quarterly basis, within an error of plus or minus two percent.

Just as it should not be felt that the accounting department is running the laboratory, adherence to a budget should not govern the director's actions in directing research work. Work should always be so planned and executed that the laboratory is not being run to meet a budget, but to secure worthwhile research and development results, and that the budget at all times is only a tool to be used to help secure these results.

When the budget is completed, not only is it known how much money is going to be spent but also how it is going to be spent with respect to fixed charges, supplies and payroll. One does not know, however, how this money is going to be spent on specific projects. At this point, the development of the program should be started, and here the director will find that the operating department of the business can really be put to work on research and development.

In General Foods, the research department has found it advantageous to draw up a suggested program for each operating division of the business. This is circulated in advance to the general manager of the division and the staff he has delegated to assist in his research planning, and a programming meeting called a week or two later. Each project listed on the program is gone over in detail and a priority list set up. After this budgeting job has been done, it is known how much money, and, therefore, how much talent can be put on the program of the particular division involved in the program meeting. Usually, it is found that the divison would like to have at least twice as much work as can possibly be carried out in the coming year. At the end of the meeting, which usually takes at least a half day, a program, consisting of A projects, which *must* be done; B projects,

which ought to be done, but not at the expense of A projects; and C projects, which are desirable if time and talent are available, is agreed upon.

It has also been decided how much effort in terms of manpower is to be put on each project. Experience makes it possible to forecast quite accurately how many dollars must be allocated to each project.

When these programming meetings have all been held, it is necessary for the laboratory director to add up his own figures and see how he comes out in relation to his overall budgeting. At this point it is often necessary to advise a divisional general manager that part of his program has to be deferred. Sometimes overall corporate management has to take a hand in deciding whose job must come first. With careful planning and full discussion, however, cases of this type are held to a minimum.

When an overall budget and a detailed program for the year have been worked out, the problem of detailed project accounting can be considered. The first principle in this respect to be observed here is to see that the detailed project accounting is accomplished with a minimum of nuisance to the research worker at the bench, and the importance of this point cannot be over-accented.

The research personnel should not have anything more to do with the system than is absolutely necessary. A motto is "Research men to do research and accountants to do accounting." Accountants, however, cannot work in a vacuum. They must have reliable basic data. The best means for securing basic data, is found to be a daily cost record card filled out by the research worker at the bench. This card looks like an ordinary time card and is divided in half hour periods covering the normal working day, with a few extra periods for overtime if necessary.

At the end of the day, or, not later than 10 o'clock the following morning, the research worker writes the project number on his card and draws a line down from this number to signify the number of half hour periods he spent that day on that particular project. If he works on one project in the morning, he writes in the project number in the first space and draws a line down to say 12 o'clock. If he spends the whole day on the project, he draws the line all the way down the card. If he works on another project when he comes back from lunch, he puts in this project number and draws a line down to the space signifying the end of the working day, and that ends his participation in the research accounting system. The cards are handed to him each day and taken up the following morning, our experience shows that this is about the only method that will work.

The accountants, wanting to save some paper, often suggest a weekly accounting card. Our experience again shows that a weekly accounting card, filled out late on Friday or on the following Monday, contains information that is the result of only an approximate guess on the part of the research worker as to what he did with his time during the week.

From here on out, the job belongs to the accountant. His part of the job will not be considered here, except to say that, if the original records are turned over to the accountant by the research man after a sincere effort on his part to make the record accurate, the accountant can keep books with just this one simple record, do it accurately, and turn out all the reports necessary to give the research director and management good financial control of research operations.

Laboratory accountants should be provided with equipment that is just as good as that provided for the general accounting department and other divisions of the business using accounting as a tool. It is believed that this is good business, just as it is good business to supply the research staff with modern facilities and equipment.